Asian Forum for Accelerators and Detectors (AFAD) 2021 March 16 ~ 18, 2021
BINP, Novosibirsk, Russia

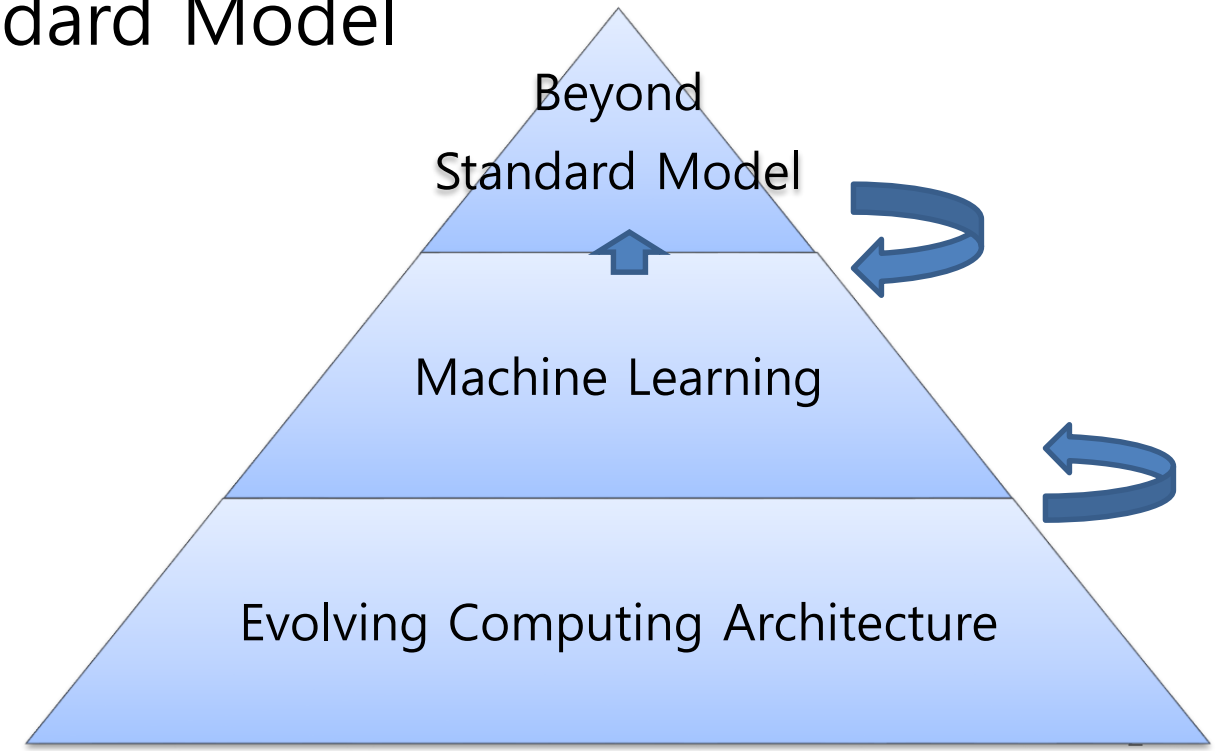
Evolving Computing Architecture for HEP research in Korea

2021. 3. 17

Kihyeon Cho (KISTI)

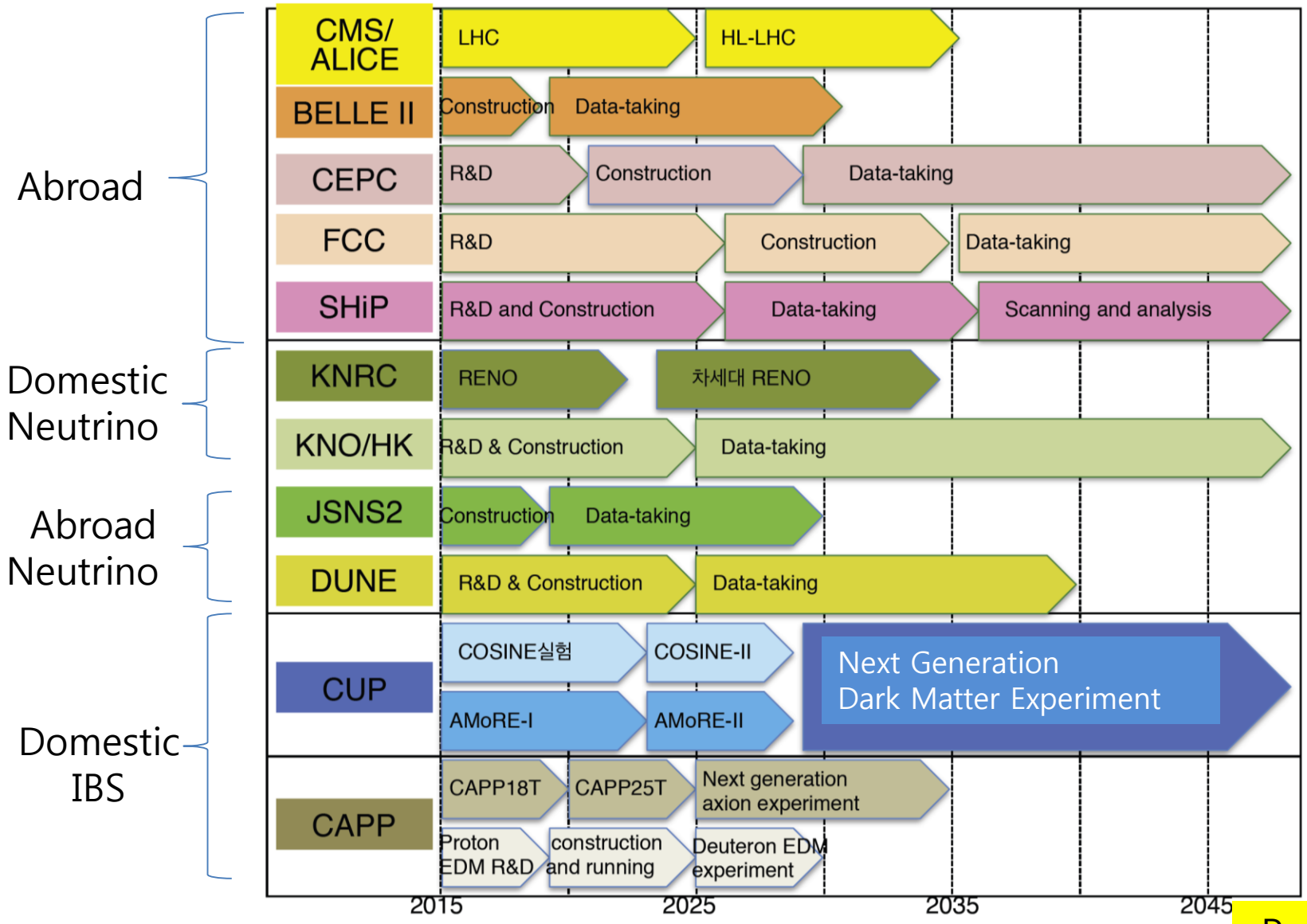
Particle physics leads IT.

1. HEP in Korea
2. Machine Learning
3. Evolving computing architecture
4. Beyond Standard Model
5. Summary



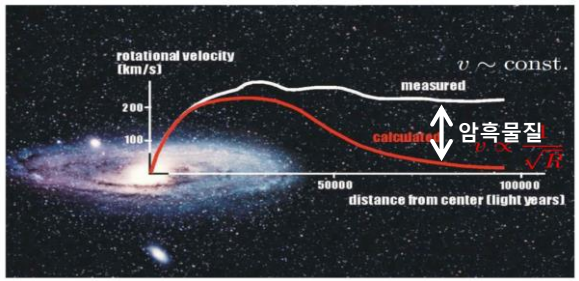
1. HEP in Korea

HEP Experiments in Korea

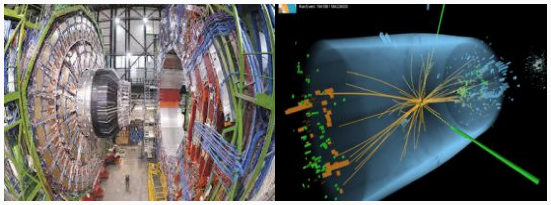


Prof. Y. Kwon

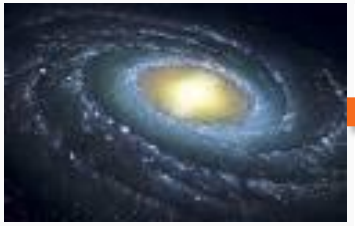
Goal is for SM or BSM.



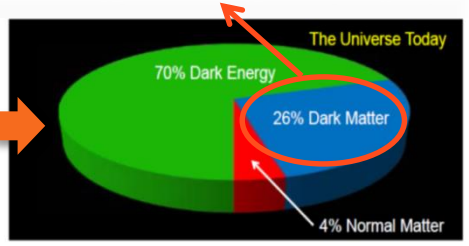
Observed data



Accelerator data

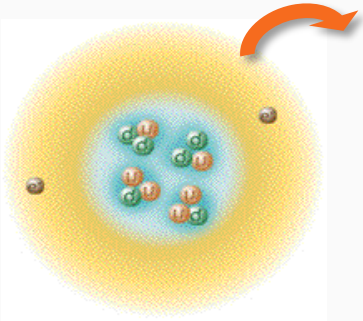


▲ Evolution of Universe

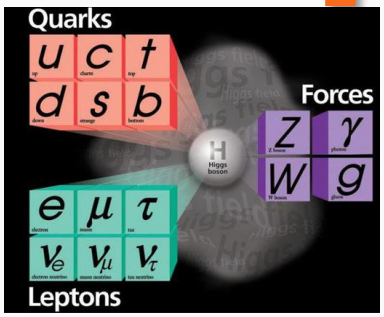


▲ Component

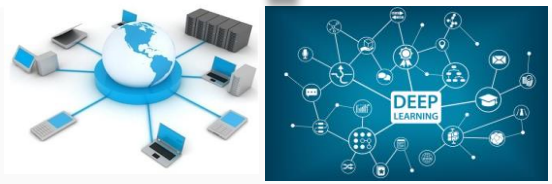
SM



▲ Origin of matter



▲ Standard Model

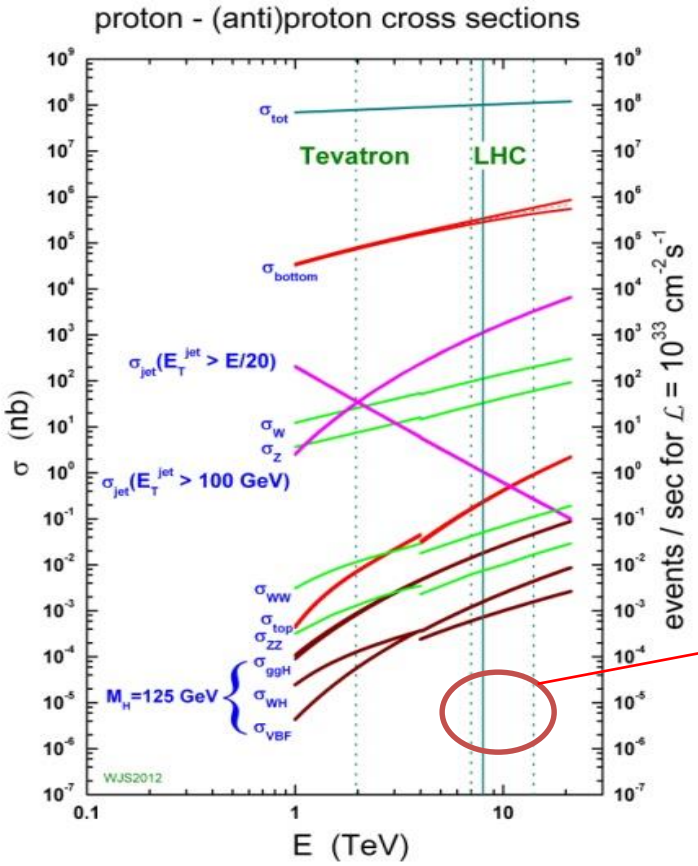


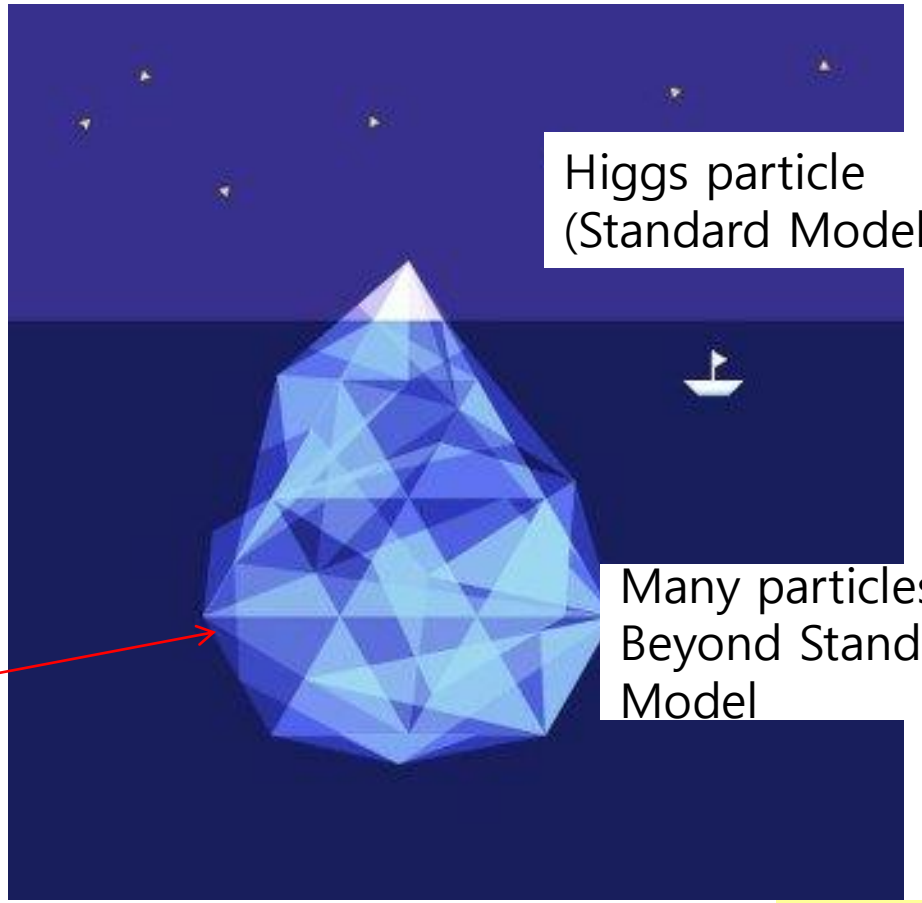
ICT

Research

Big data / Deep Learning

Beyond the Standard Model





Adam Martin

⇒ BSM needs at least 1000 more Higgs events.

⇒ ML & Evolving computing architecture needed

Exp.

Obs.

Big Data Production

● Fermi telescope

● CERN(CMS, ALICE, SHiP)

KiSTi www.kisti.re.kr

● KEK(Belle II)

NET-WORK

● Fermilab(DUNE)

● Experimental data

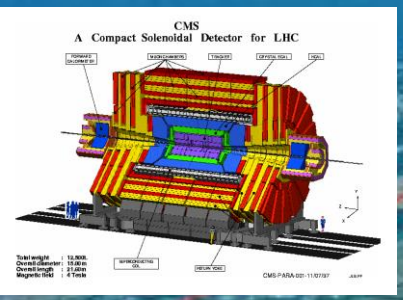
● Observation data

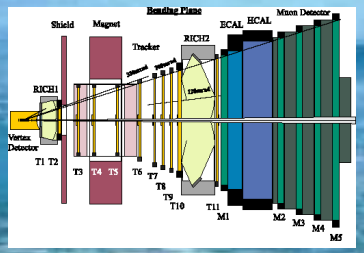
Year	Experiment	Data size
1999~2010	Belle	~1 PB
2008~current	LHC(CMS)	10~20 PB/year
2019~2025	Belle II	100 PB
2025~	HL-LHC(CMS) DUNE	100PB/year (5~10 times of current)

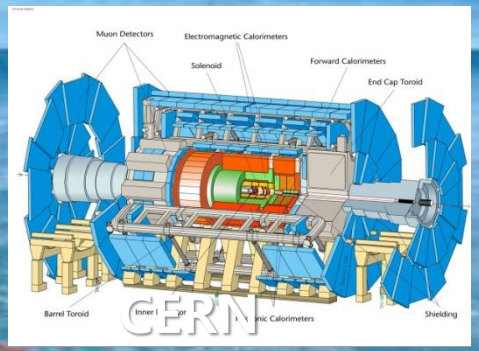
● LSST

● ICECube

Large Hadron Collider







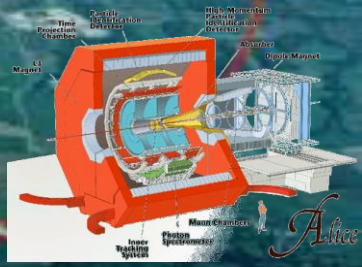
LHCb

ATLAS

CMS

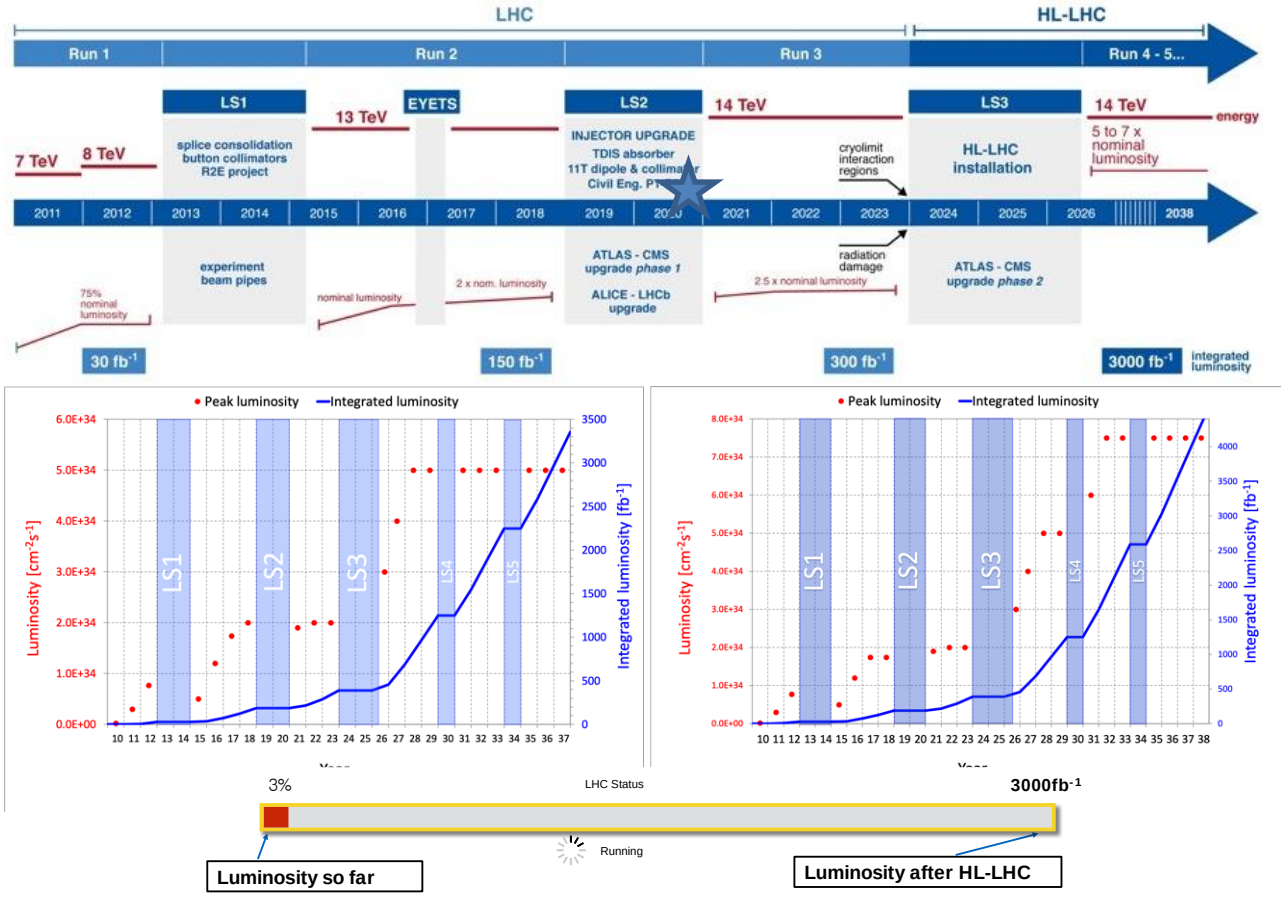
	Beams	Energy		Luminosity
LEP	e+ e-	200	GeV	$10^{32}\ cm^{-2}s^{-1}$
LHC	p p	14	TeV	10^{34}
	Pb Pb	1312	TeV	10^{27}

ALICE



LHC at CERN

Big Data in High Energy Physics



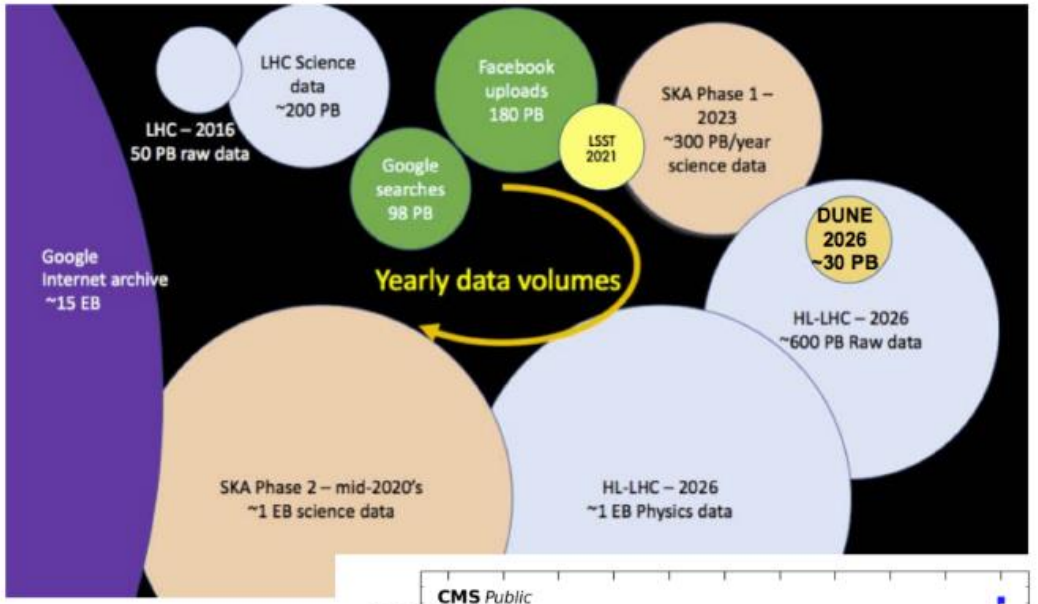
HL-LHC statistics ⇒ DUNE & LSST

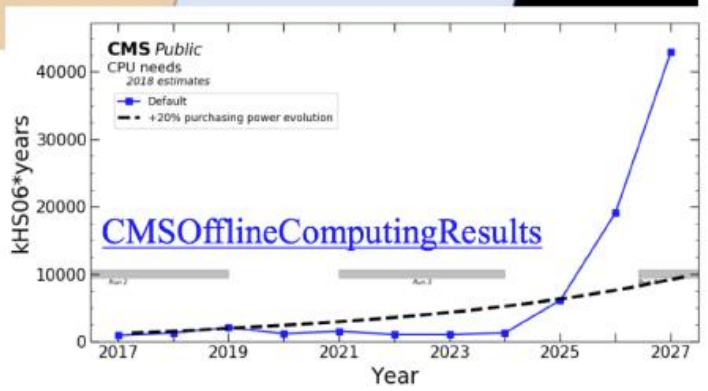
- x10 data vs. LHC Run 2/3,
- 200 simultaneous collisions vs. ~30 in Run2
- 15~65 increasing channels

J. Goh

Big Data in High Energy Physics

LHC Data volumes will approach scale of Google and Facebook.

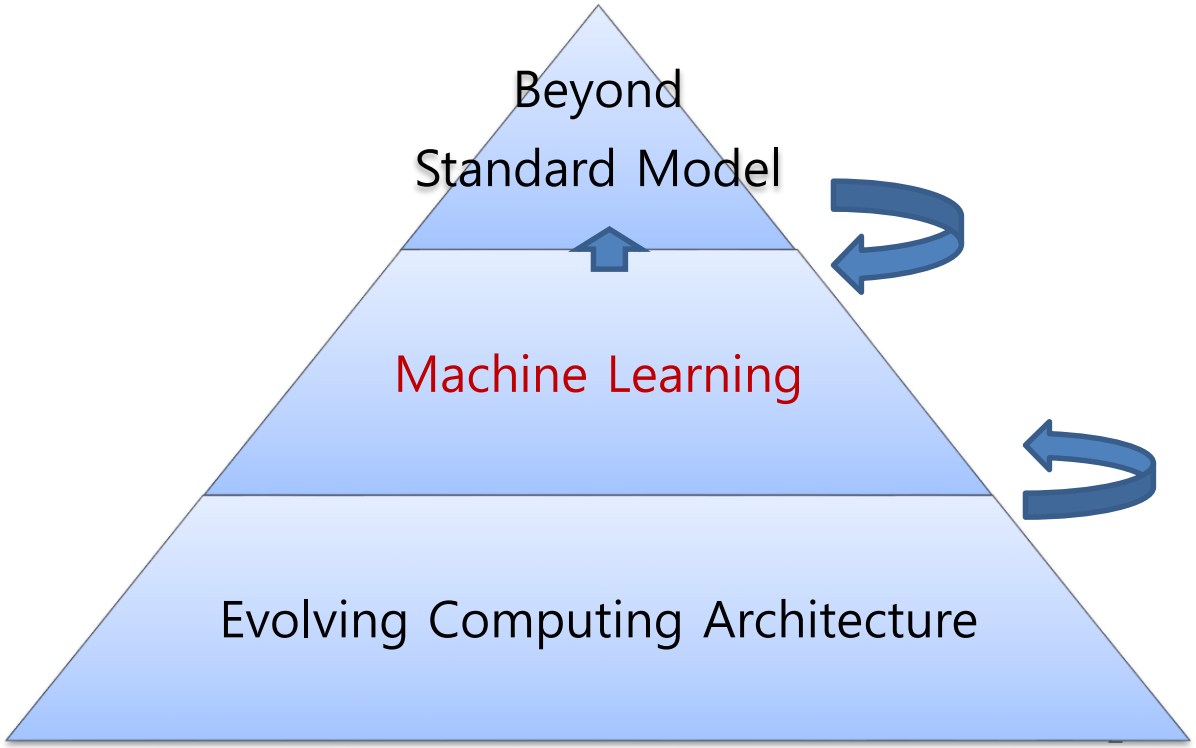




⇒ ML & Evolving computing architecture needed

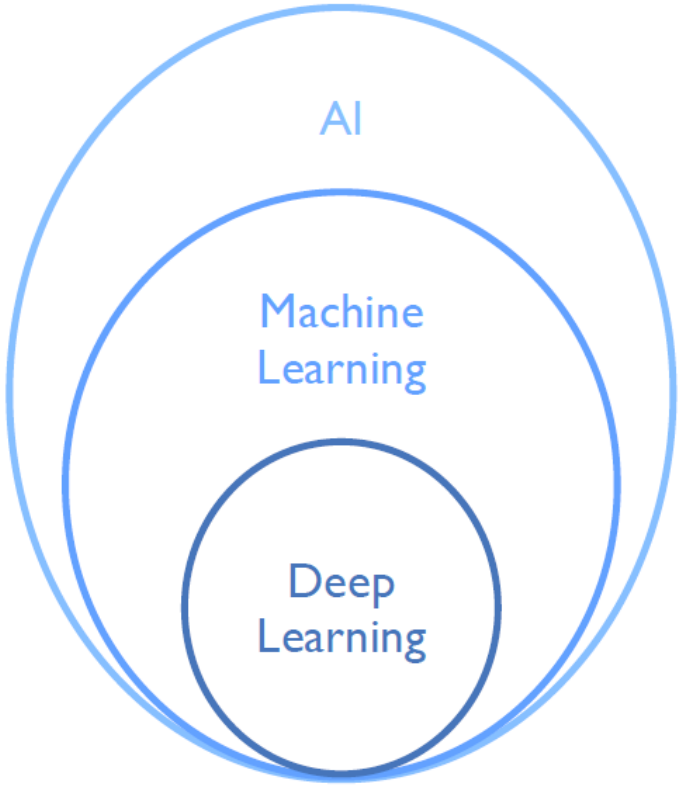
Prof. C.S. Moon

2. Machine Learning



Machine Learning in HEP

Deep Learning



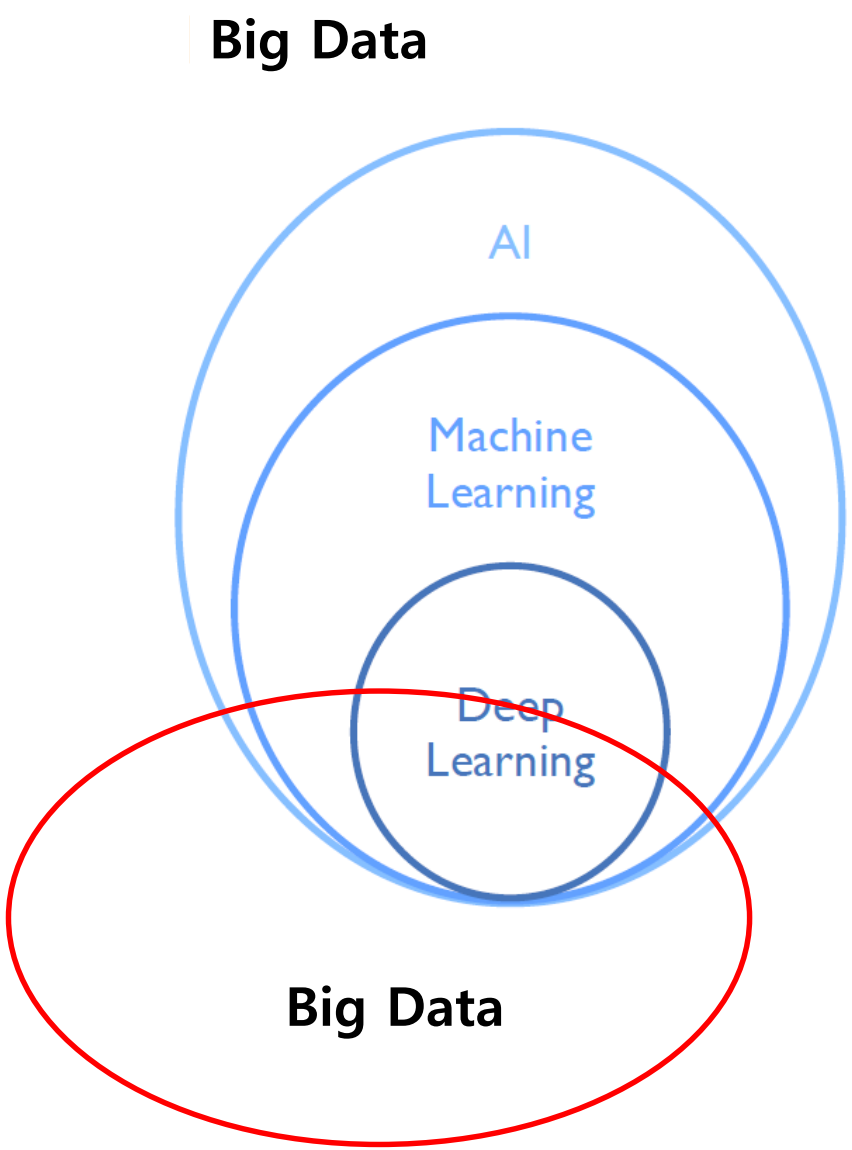
Programs that can learn and reason like humans

Algorithms that learn from examples ("glorified curve fitting")

A class of ML algorithms whose fitting functions consist of multi-layer neural networks

David Shih

Machine Learning in HEP



- ML needs big data in order to achieve a good accuracy on its predictions.
- Big data experiments like LHC are an excellent laboratory to test ML.
- To manipulate big data, several tools are needed to process the information.

H.D. Yoo

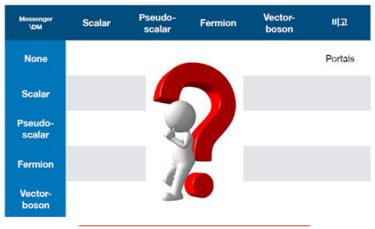
Big data

Theory

Big data

Machine Learning

Hidden Information



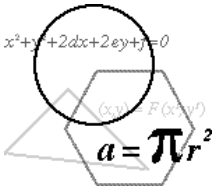
Model

Fast processing

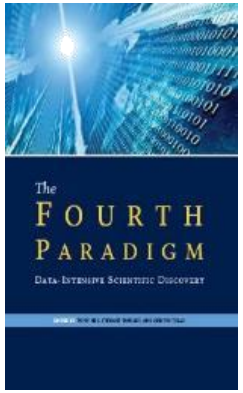
Precision

New particle

The changing nature of scientific research

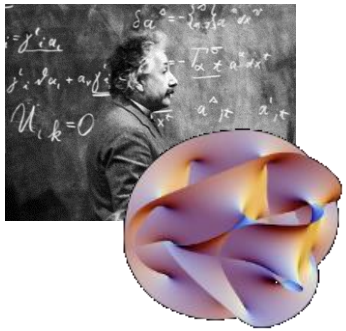


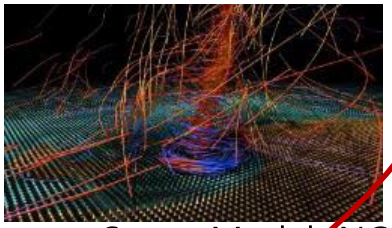
$$H(t)|\psi(t)\rangle = i\hbar\frac{\partial}{\partial t}|\psi(t)\rangle$$



Experimental → Theoretical → Computational Simulation → Data and Machine Learning

Large Hadron Collider



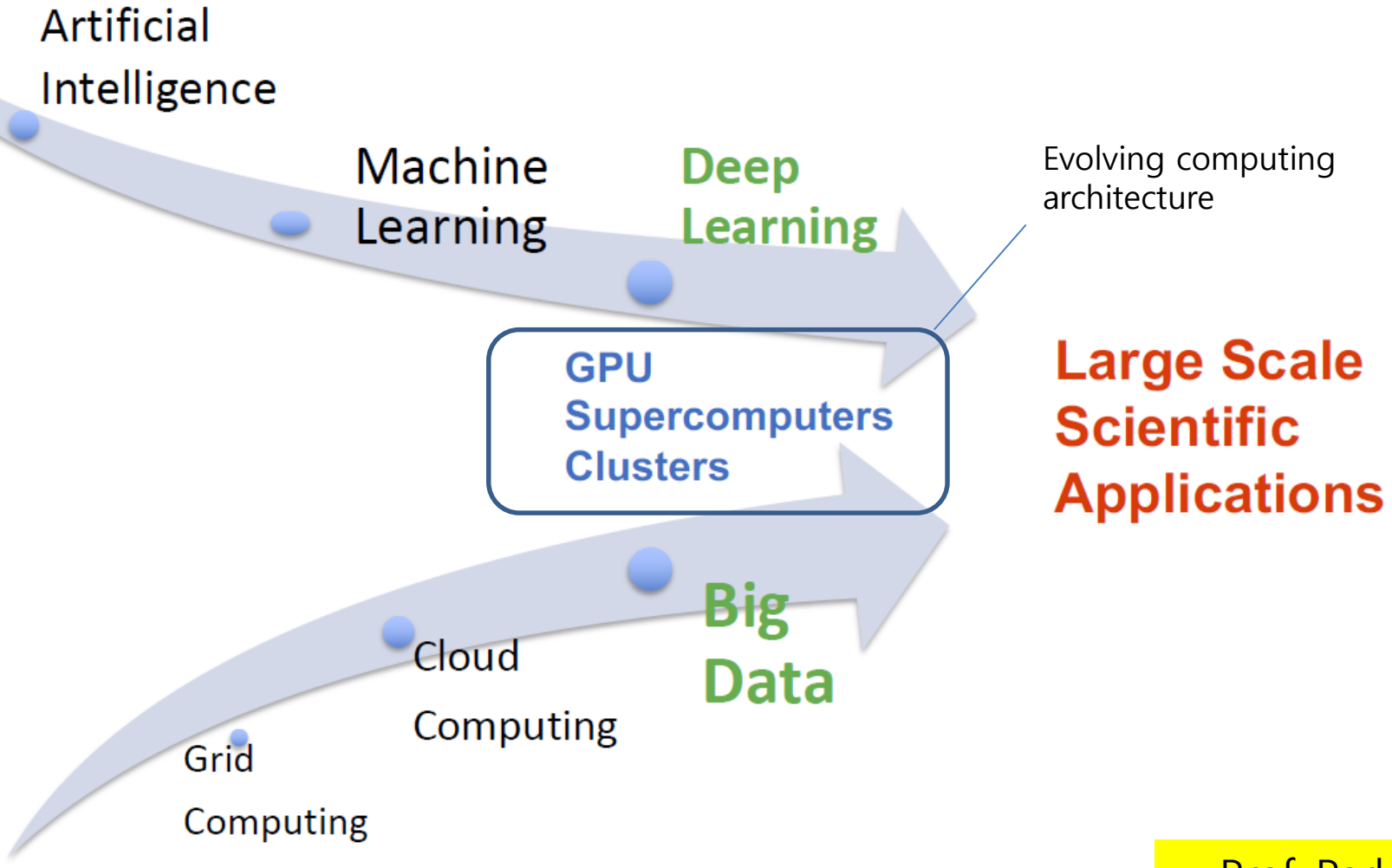


Severe Storm Model (NCSA)

ARRAY OF THINGS

e-Science

Big data & Deep Learning for Large Scale Scientific Applications

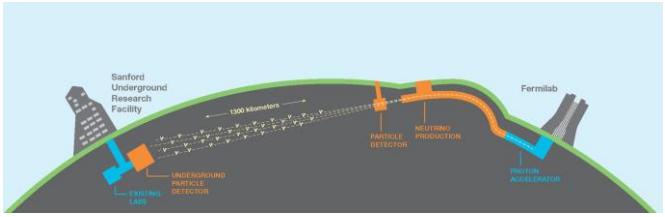


Prof. Park

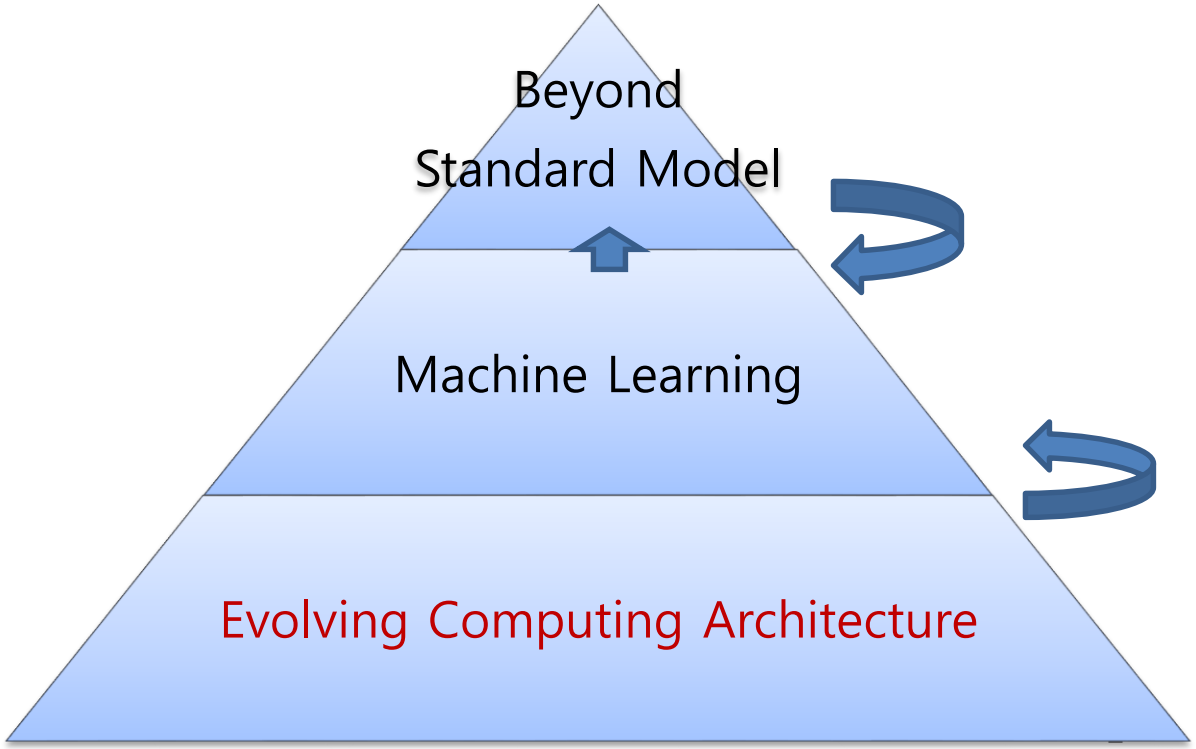
Moving towards HPC

- DUNE has used Grid Farm and Cluster, the computing power of conventional HEP experiments.
- However, research using HPC is also underway due to the evolving computing architecture.
- Attempt to submit a job using the KNL system of NERSC's Cori supercomputer
- Applying to CP Violation's sensitivity setting study for TDR
- Supercomputer uses CVMFS to bring environment variables fitting and DUNEL library.
- It will be used for KISTI-5 Supercomputer of KNL system.

DUNE DEEP UNDERGROUND NEUTRINO EXPERIMENT



3. Evolving Computing Architecture



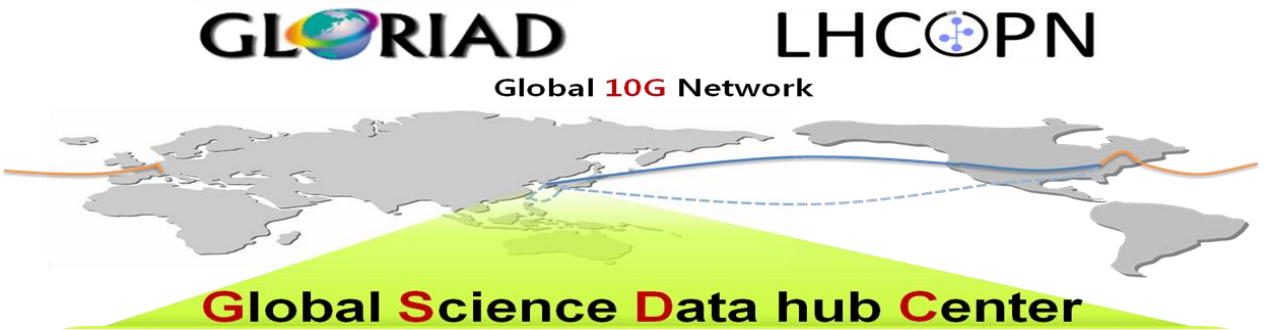
HEP Computing in Korea

- From Grid Farm
  - Soongsil U. & Yonsei U.
    - Belle Farm
  - KNU & U. of Seoul
    - CMS Tier-3
  - KISTI-GSDC
    - ALICE Tier-1, CMS Tier-2,3
    - Belle Farm, LIGO, RENO
- To evolving computing architecture
  - KISTI-5 supercomputer

From Grid Farm
To evolving Computing Architecture

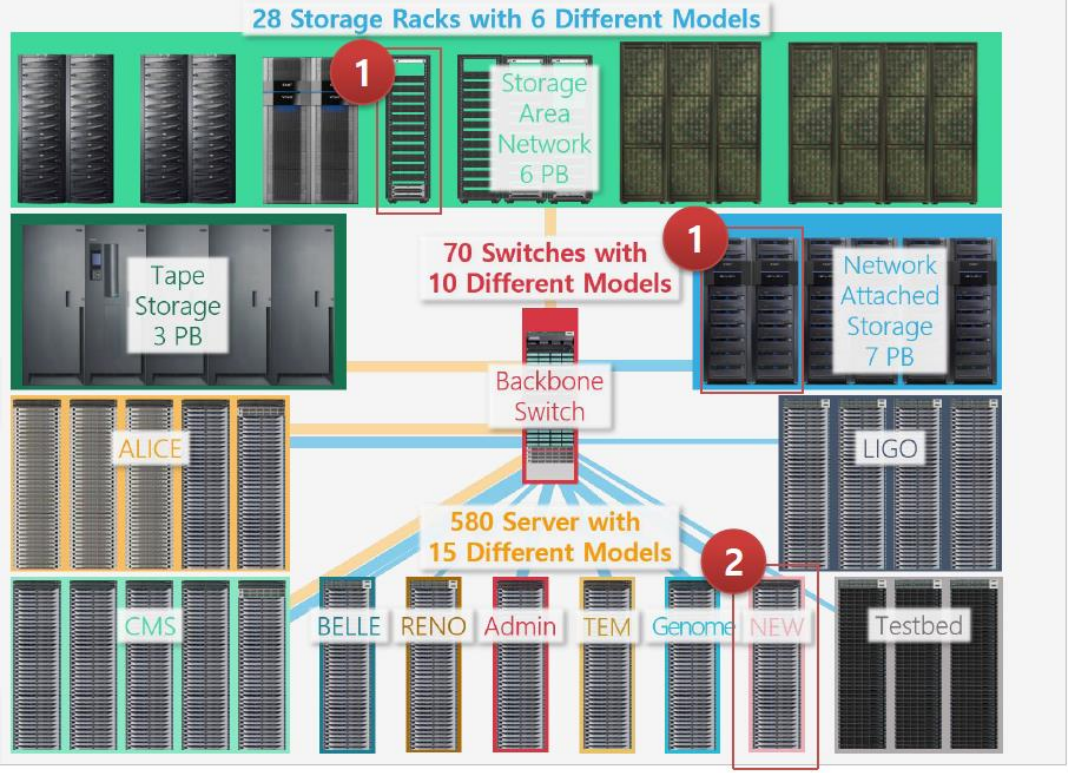
KISTI-GSDC

- ALICE Tier-1, 3
- CMS Tier-2, 3
- Belle II Farm
- LIGO Farm
- RENO
- PAL
- Etc.

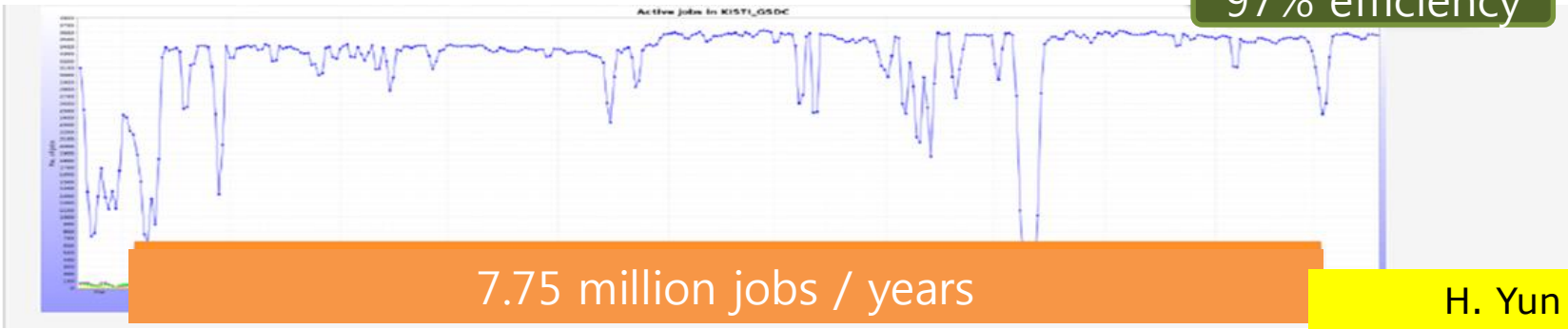


- Resources for HEP (2020)

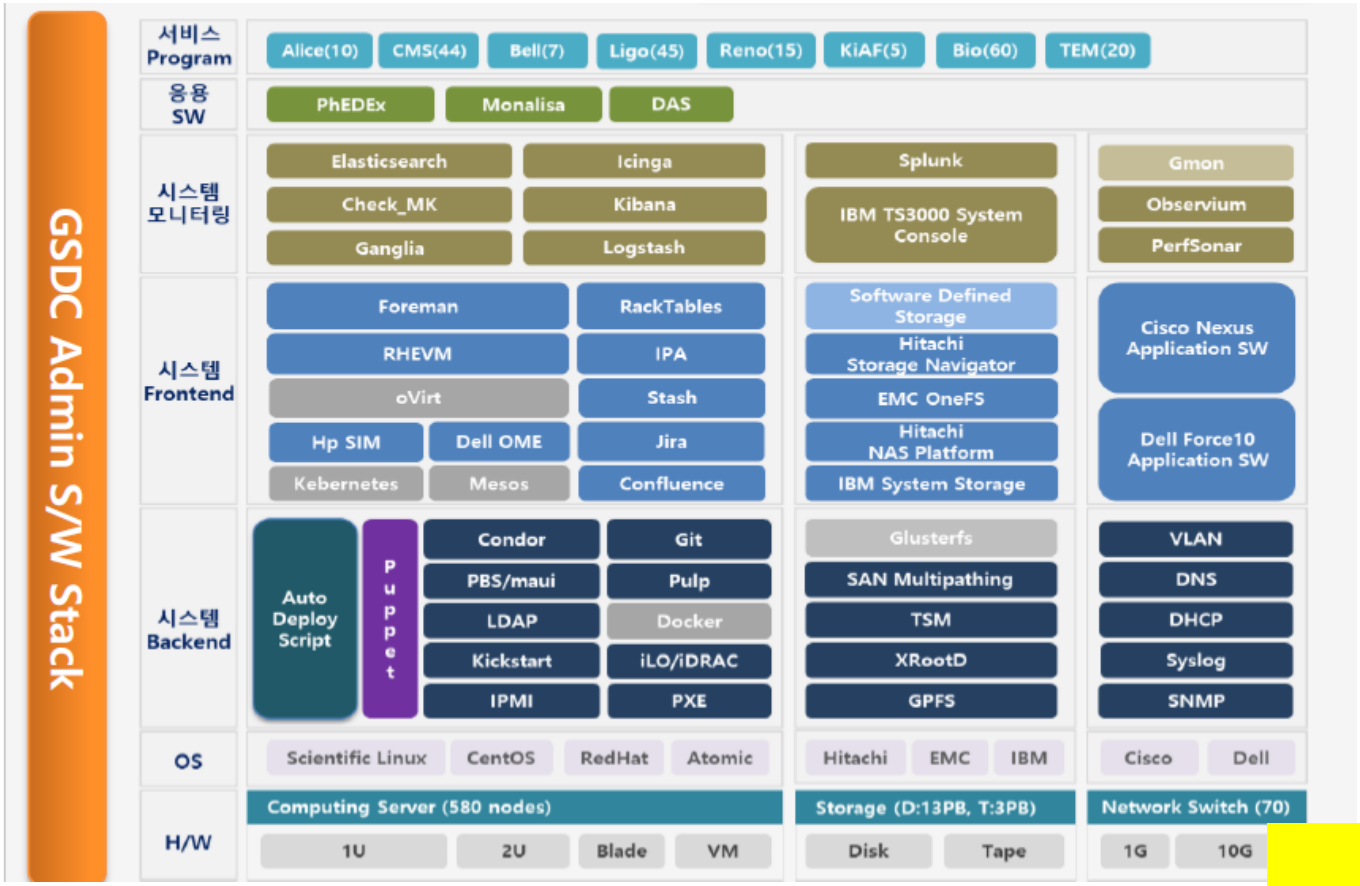
	CPU (Physical core)	DISK (TB)	Tape (TB)
ALICE T1	1940	4000	3200
CMS T2	500	1000	
ALICE T3	400	1300	
CMS T3	1000	1000	
LIGO	996	550	
Belle II	156	107	
RENO	432	1100	



- To run Tier-1 and Tier-2
  - Maximum 3680 jobs simultaneously
  - 97% efficiency



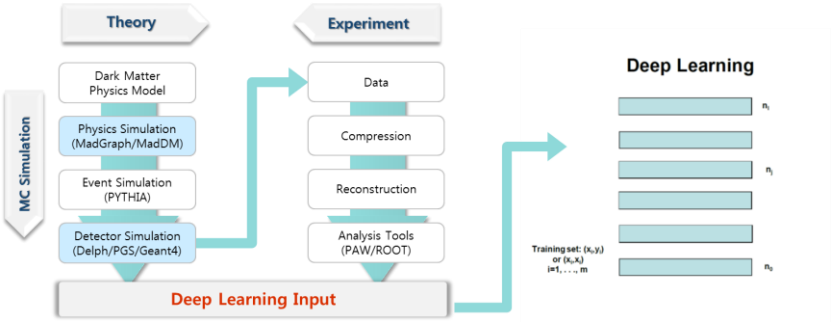
- Software and Middleware
  - More than 60 open S/W
  - More than 100 M/W and service programs

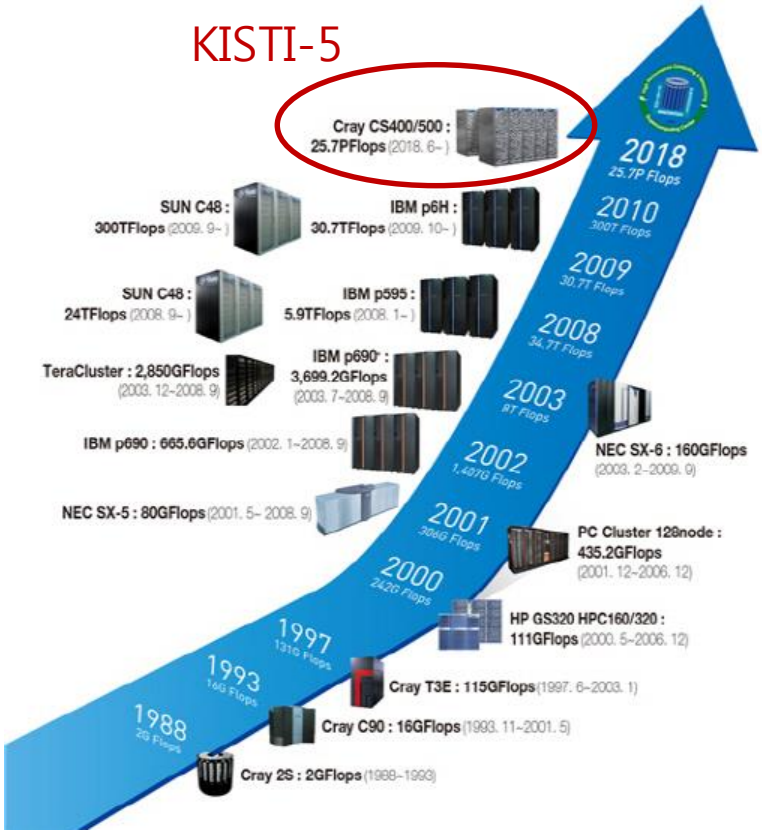


H. Yun

From Grid Farm
To evolving Computing Architecture

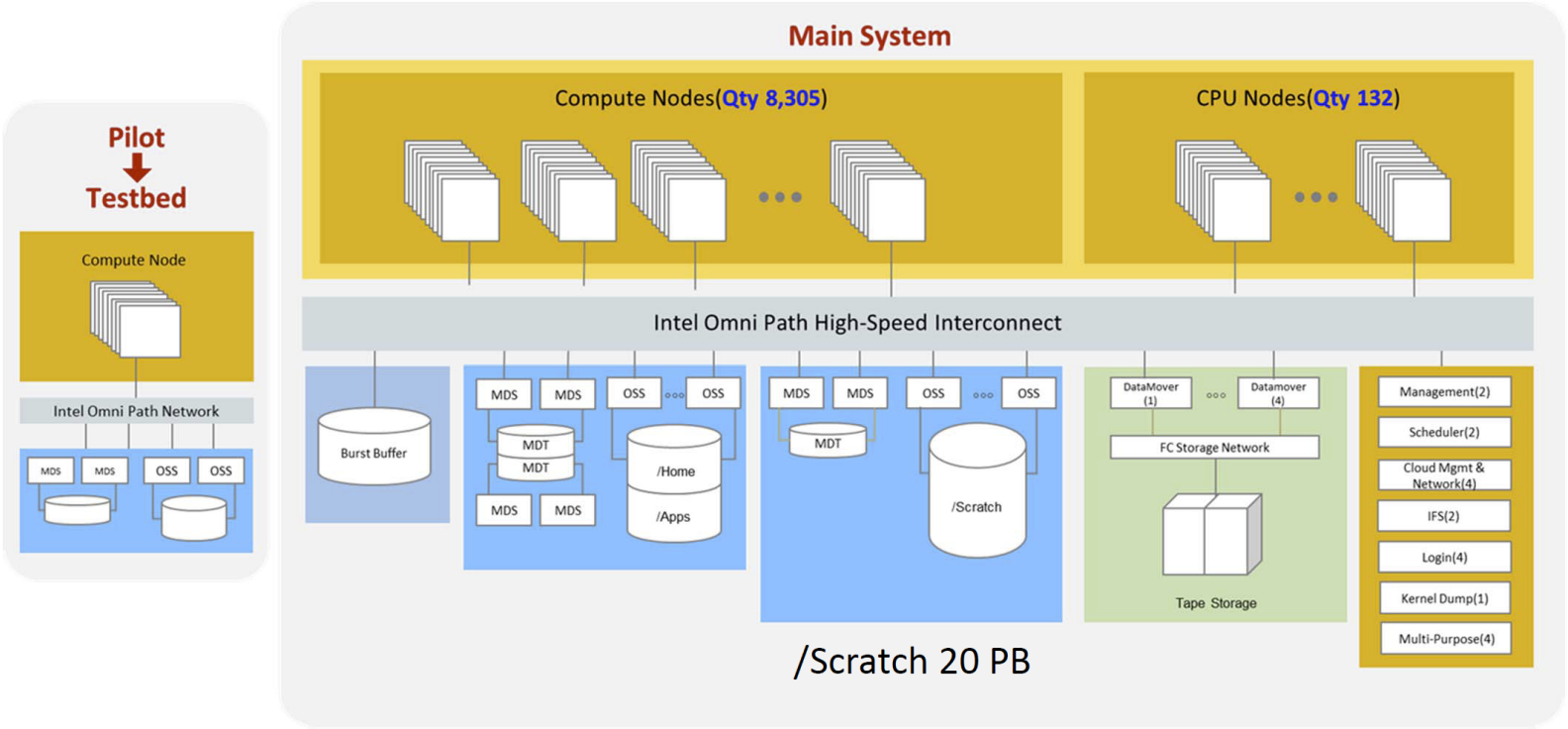
KISTI-5 supercomputer





- Overview
  - CPU 25.7PF
    - Heterogeneous: 25.3PF CS400 w/KNL
    - CPU-only: 0.4PF CS500 w/Skylake
  - Storage
    - 21PB SPS
    - 10PB Archive
  - Launched in November 2018

Architecture of KISTI-5 supercomputer



/Home 0.5 PB /Apps 0.5 PB

Burst Buffer 0.8 PB (SSD)

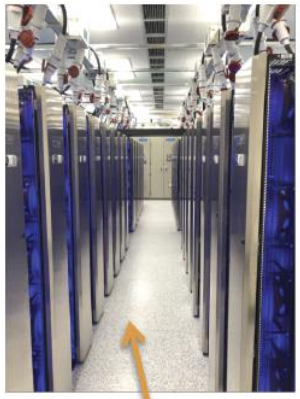
Tape Storage 10 PB

@ 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

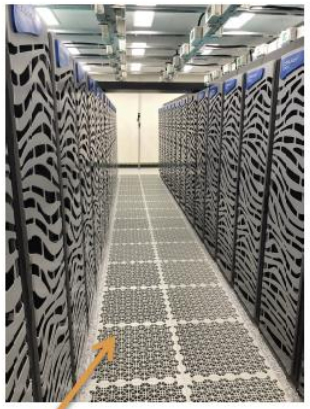
M.S. Joh

Rack Front Door

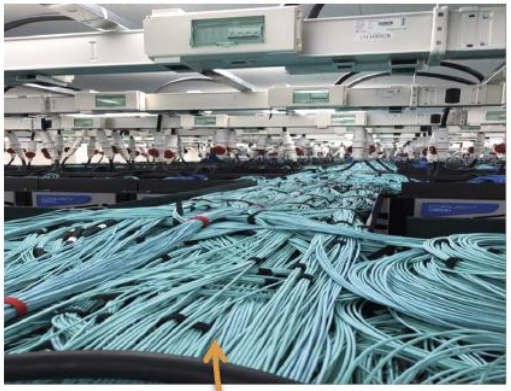
Rack Rear Door



Hot Aisle

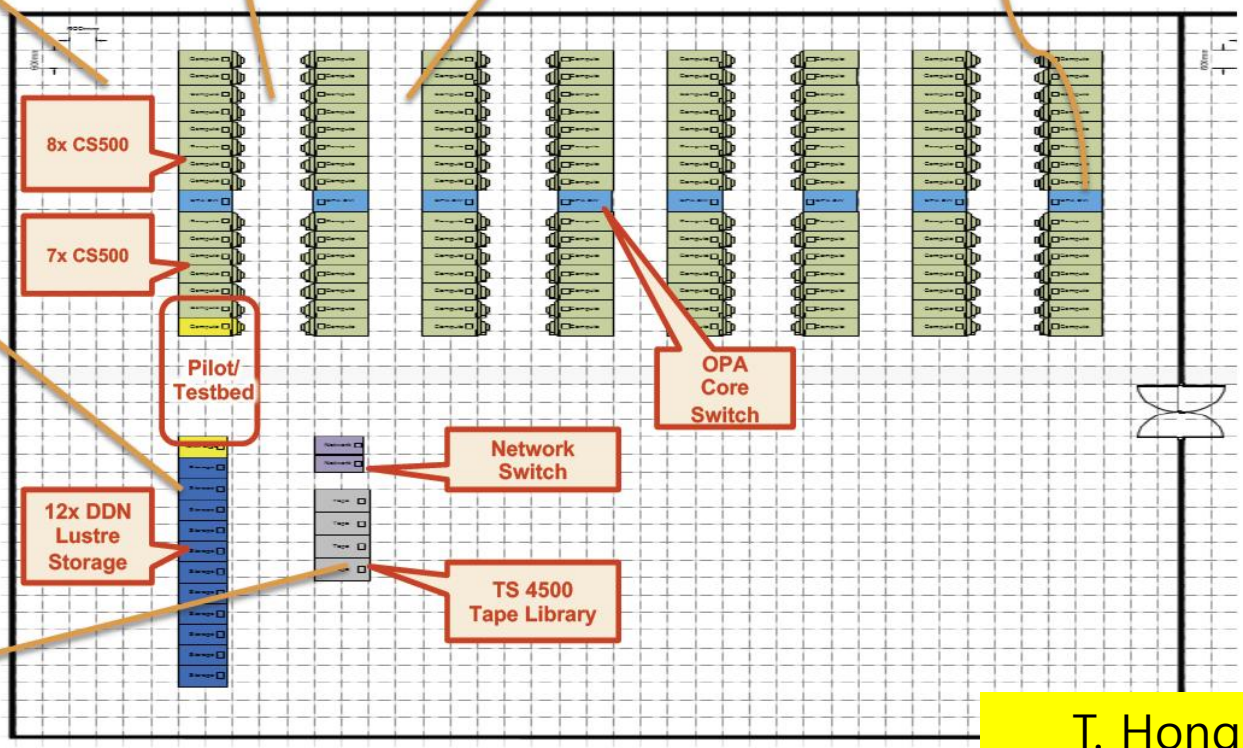


OPA Optic Cables



Disk Storage (21PB)

Tape Storage (10PB)



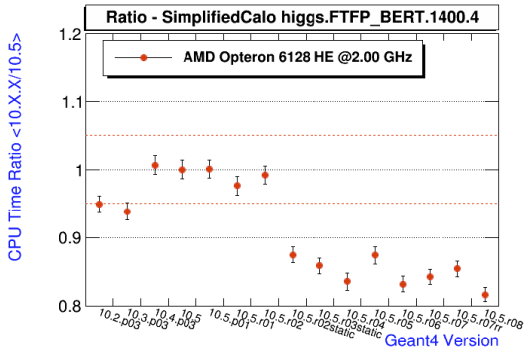
T. Hong


국가슈퍼컴퓨팅센터

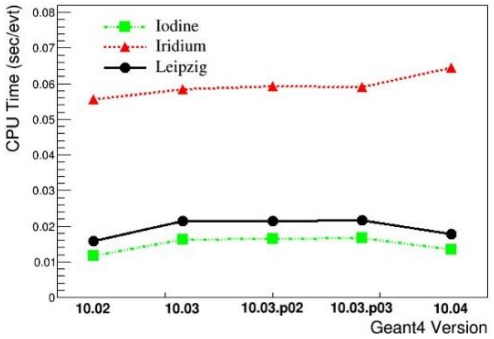

DataDirect Networks

Profiling

- Using Geant4 tool kit
  - High energy physics profiling (Fermilab)
    - SimpliCarlo (Sequential)
    - CMSExp (Multi-Thread)
  - Low energy physics profiling (KISTI)
    - Using Brachytherapy code
    - KISTI-5



Julia Yabara

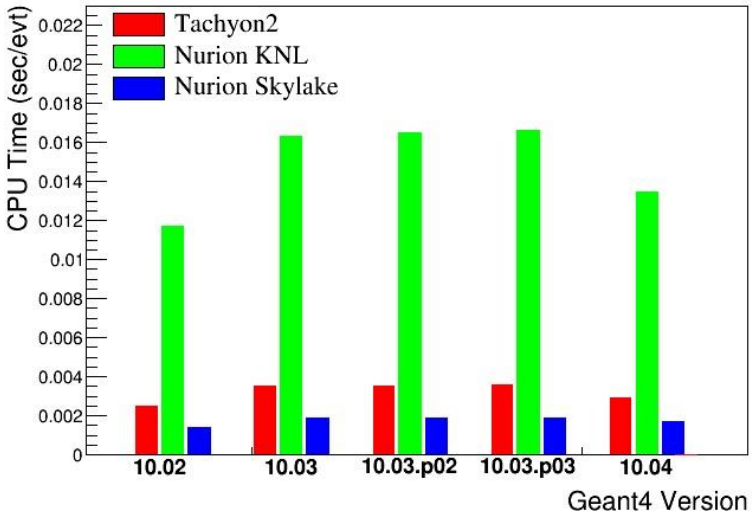


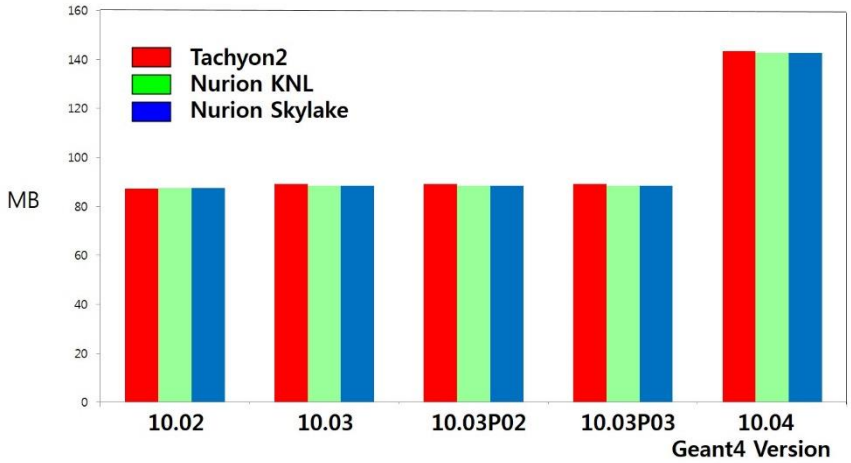
KISTI-4 vs. KISTI-5

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

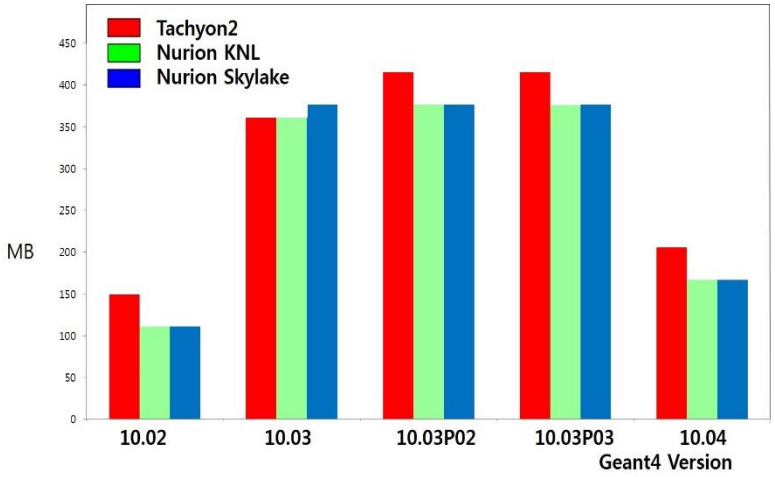
KISTI4 vs. KISTI5

- KISTI4
  - Tachyon2 (CPU only)
- KISTI5
  - Nurion KNL (Heterogenous)
  - Nurion Skylake (CPU only)





Memory in the first event



Memory in the last event

Columnar Analysis in High Energy Physics

Back-end
Format the data from ROOT ntuples into columns (awkward arrays)

Front-end
Define signal and control regions, apply corrections, produce histograms

- Support for several "column-delivery" mechanisms
- Choice of mechanism should be transparent to the user

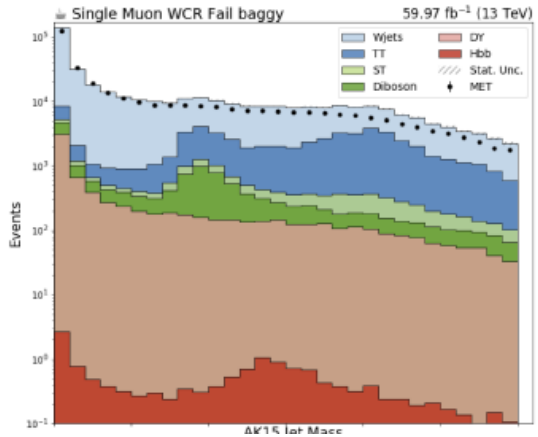
- Convenient ways to wrap awkward arrays
- Histogramming tools based on matplotlib
- Lookup tools for the easy application of weights and scale factors

HTCondor High Throughput Computing

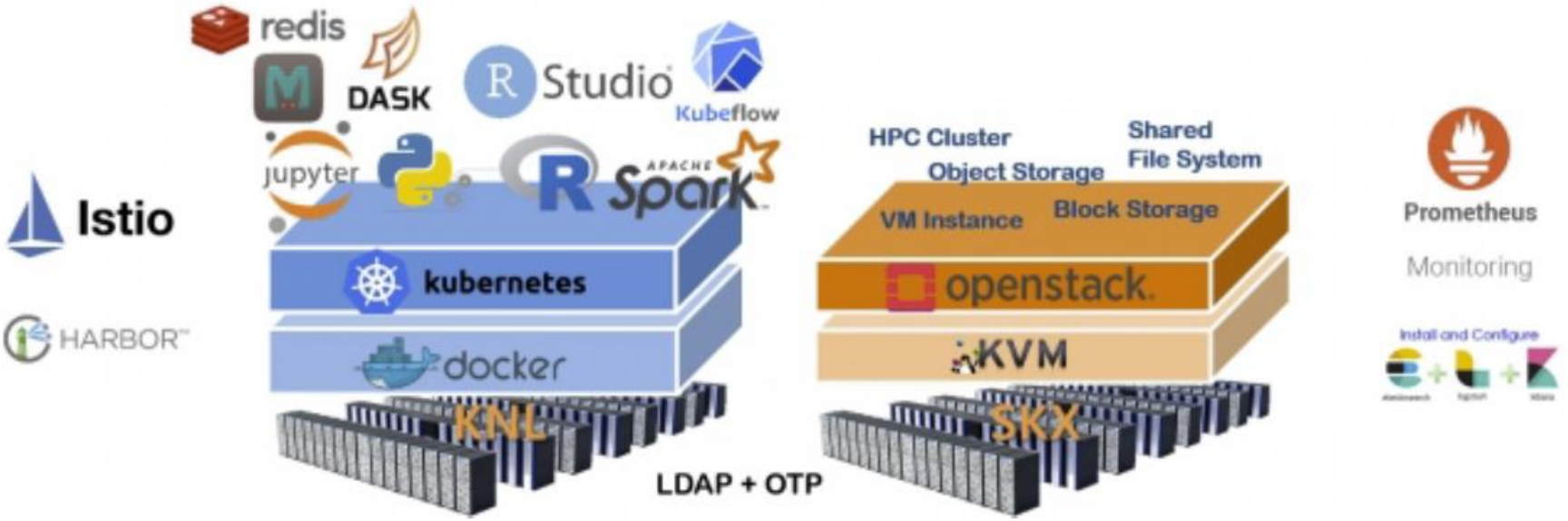
DASK

uproot

APACHE Spark™



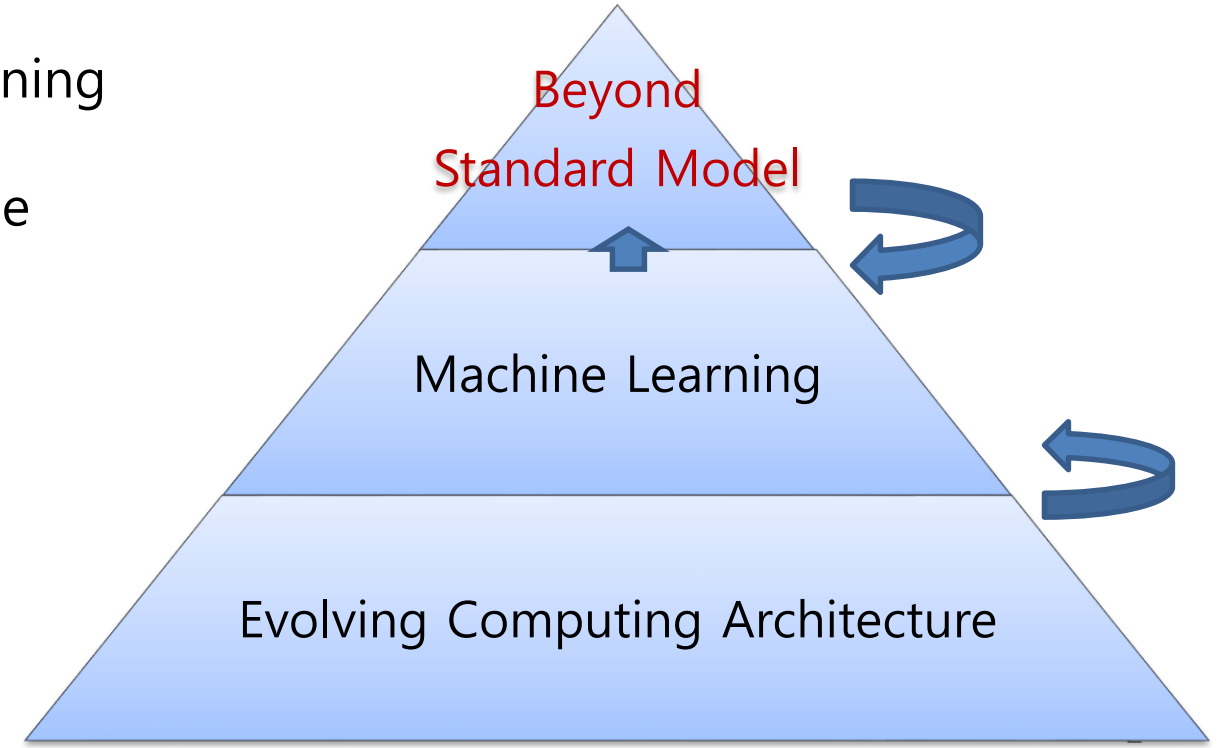
KISTI Cloud Service for High Energy Physics



- Recently 'KI(KISTI Intelligent) Cloud' service has been started
  - It allows users to use Nurion via the cloud service.
- Some frameworks (services) might be suitable for HEP .

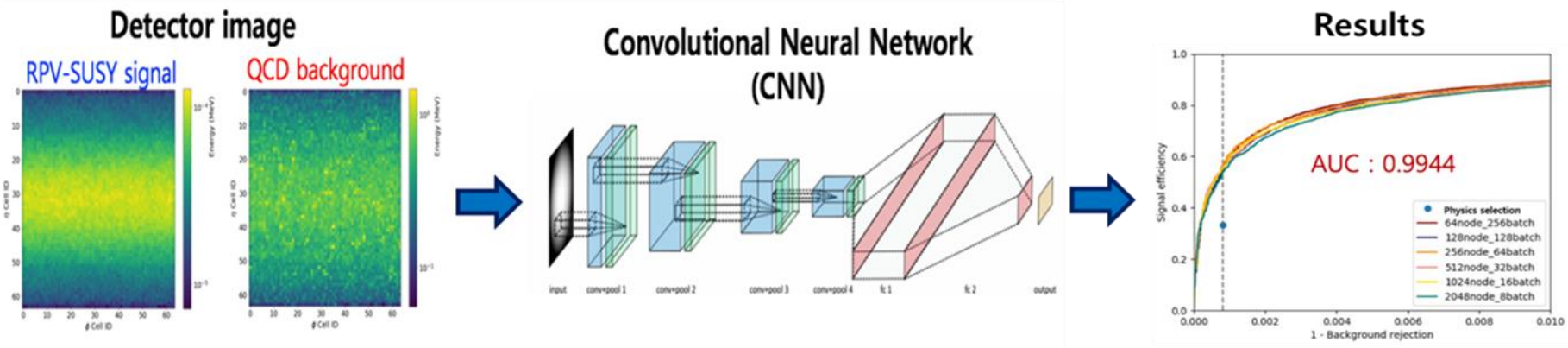
4. Beyond Standard Model

- LHC with Deep Learning
- Evolution of Universe



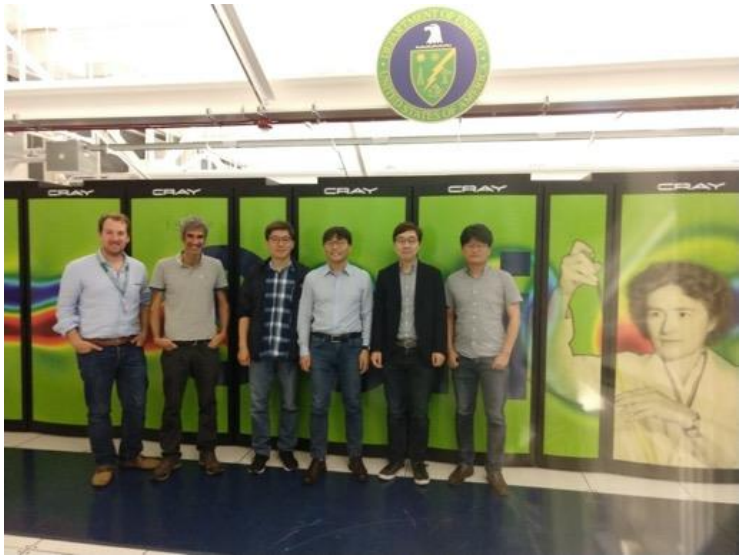
LHC with Deep Learning

- Using 4096 nodes of KISTI-5 Supercomputer, we have performed deep learning using CNN on 7 layers or higher.
- Used CMS data with the world's largest CPU
  (cf. US NERSC uses machine learning in ATLAS experiments)
- Separating SUSY signal events from QCD background events



The result of large-scale deep learning with 7 layers using KISTI-5 supercomputer (4096 nodes)

- Working with NERSC for ML
  - NERSC has KNL system of Cori
    while KISTI has KNL system of KISTI-5.
  - NERSC uses ATLAS data
    while KISTI uses CMS data.

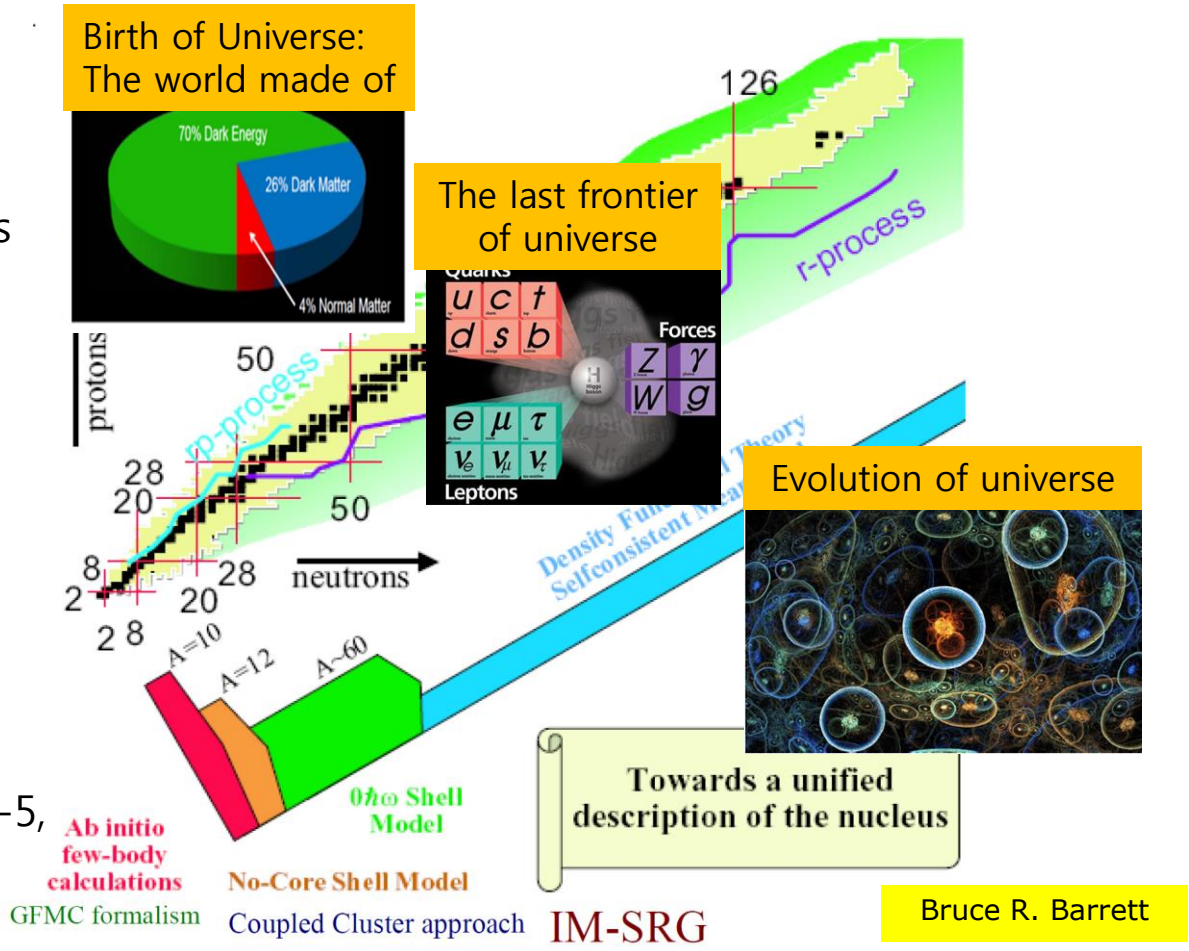


Cori @ NERSC

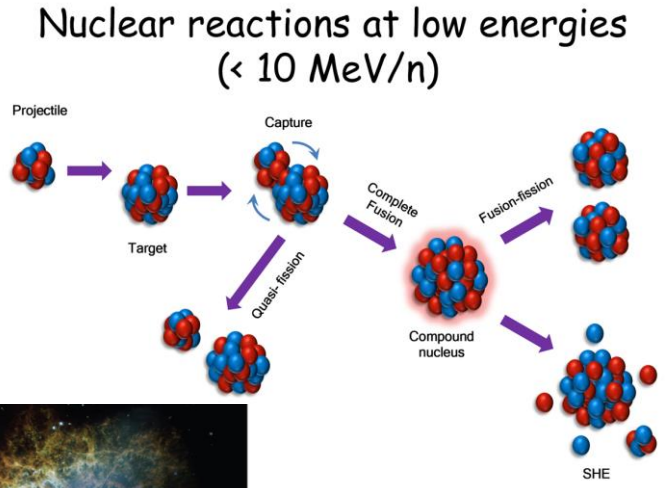
KISTI-5 supercomputer @ KISTI

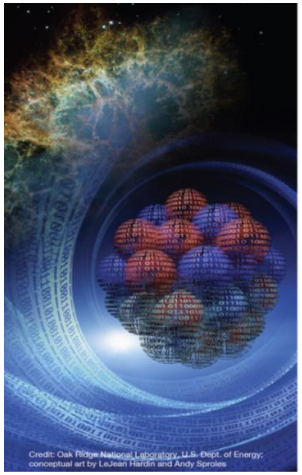
Evolution of Universe

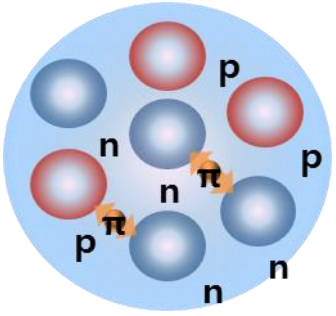
- Dark Matter Experiment
  - The characteristic & reaction of rare isotopes are important.
- Nuclear Chart
  - The secret of birth of universe ⇒ dark matter
  - The origin of element of universe
  - The evolution of star
- Using 235 accounts of KISTI-5,

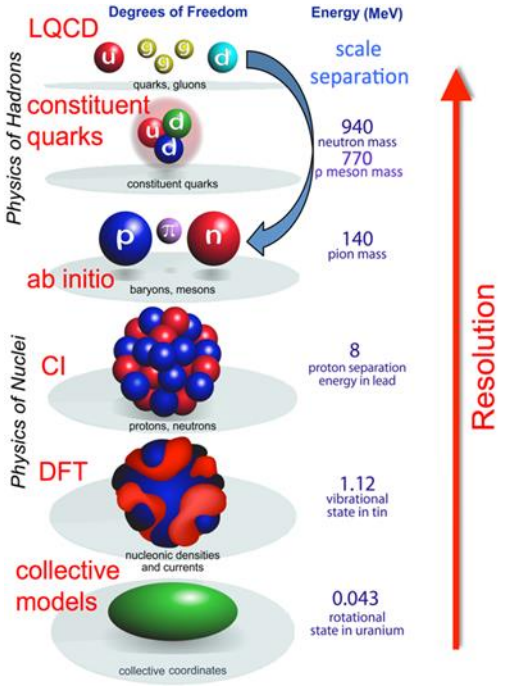


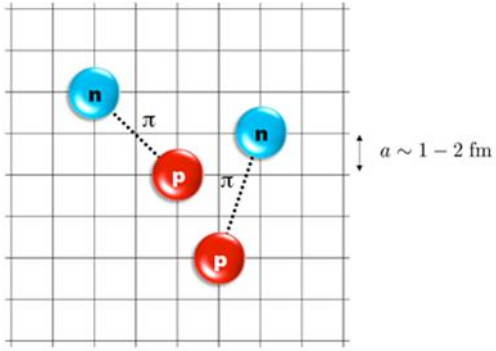
- Production of exotic nuclei and heavy elements
- Nuclear Structure and reactions from first principle
- Lattice Effective Theory

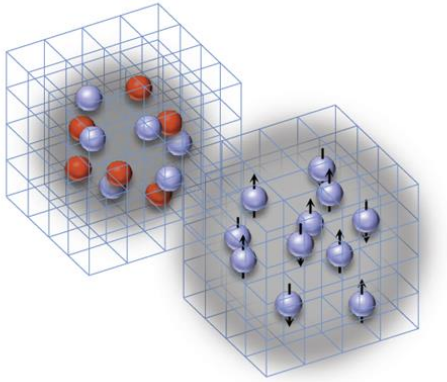




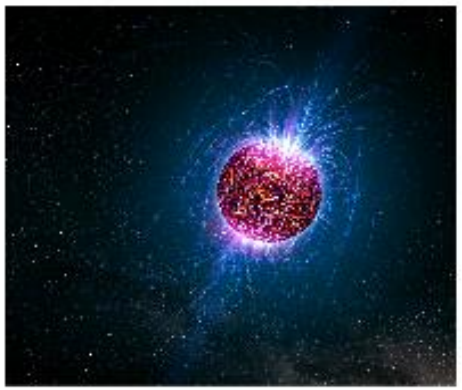


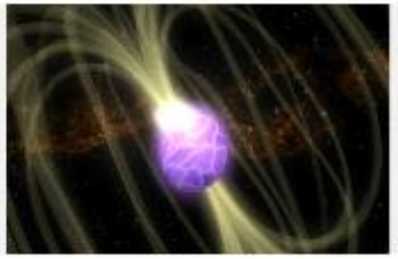






Discovery





Dynamic/transport properties of neutron star crust solved

Static properties of neutron star crust solved

Predict shell structure of extreme nuclei

10x tera | 100x tera | peta | 10x [illegible]a | 100x peta | 1 exaflop year

5. Summary

- New physics beyond Standard Model needs machine learning and evolving computing architecture.
- HEP computing merges from Grid Farm to evolving computing architecture.

⇒ Therefore, KISTI-5 will play an important role to study HEP in Korea besides Grid farms.

Acknowledgment

- Dark matter research cluster

Thank you.
(cho@kisti.re.kr)