

HIGH ENERGY ACCELERATOR RESEARCH ORGANIZATION

# COMPUTING RESEARCH CENTER



Inter-University Research Institute Corporation  
High Energy Accelerator Research Organization

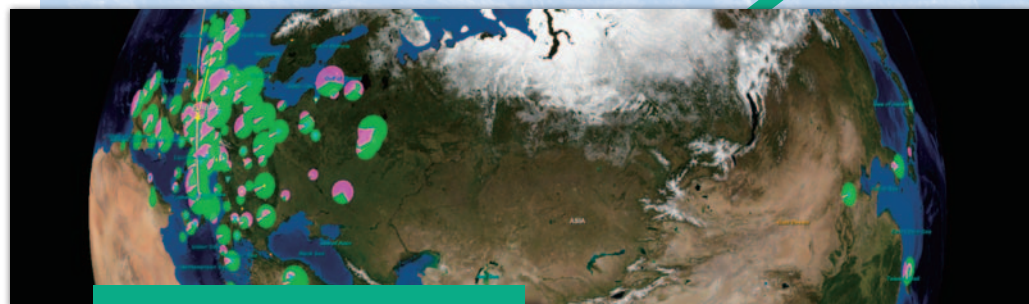
Computing Research Center

# Computing Research Center



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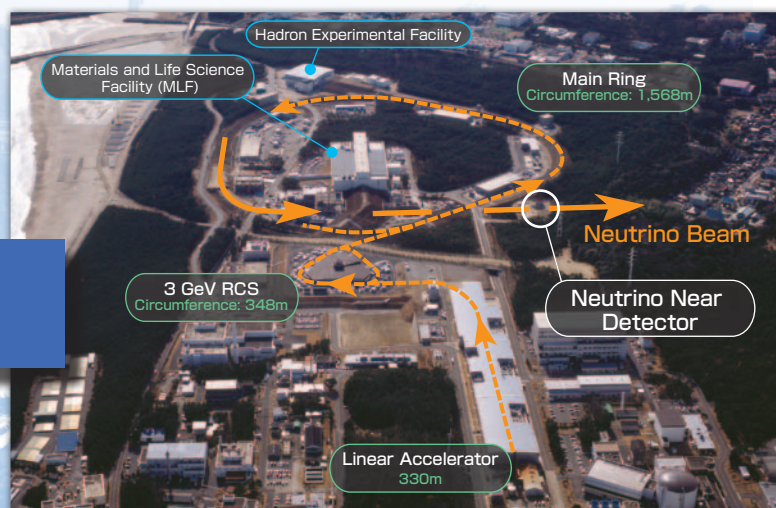


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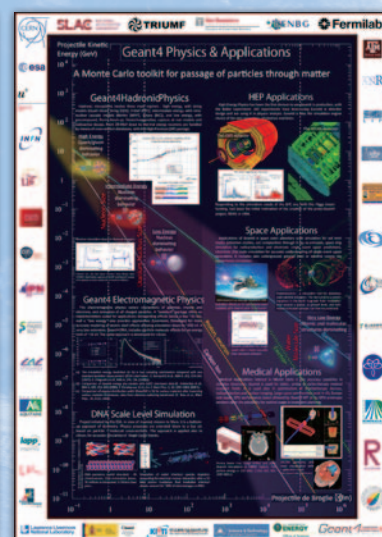
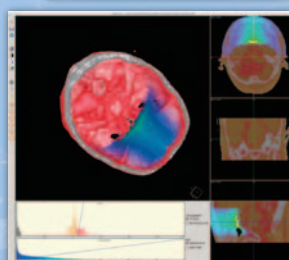
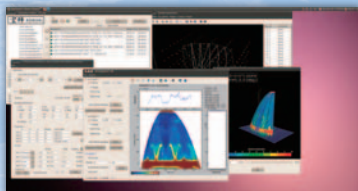
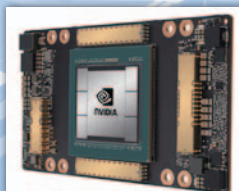
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# Central Computer System

KEK uses the Central Computer System (KEKCC) for various research activities. The Data Analysis System in KEKCC is primarily used to analyze experimental data. KEKCC also provides IT infrastructures such as the E-mail system and different Web services.



## Work/Computing Server

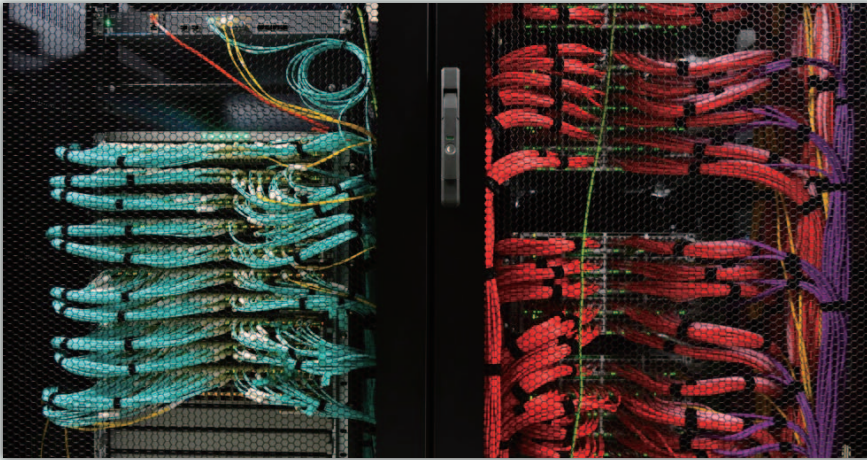
The Data Analysis System provides high-performance computing servers and a large-capacity storage system to accumulate and analyze a large amount of experimental data. The computing servers, which have approximately 15,000 CPU cores, are used for interactive and batch analysis. The storage system has a 25.5 PB disk system and a tape library with a maximum capacity of 100 PB. These high-spec storage systems enable to process experimental data with high-throughput.



Lenovo ThinkSystem SD530/SR630 15,000 cores



## Network connecting the Systems



External connection: Cisco Nexus 9516 / Juniper SRX4100



Interconnect fabric: Mellanox CS7500 4xEDR

## Disk Storage System



IBM Elastic Storage Server GL4C (25.5PB)

## Mail System · Web System

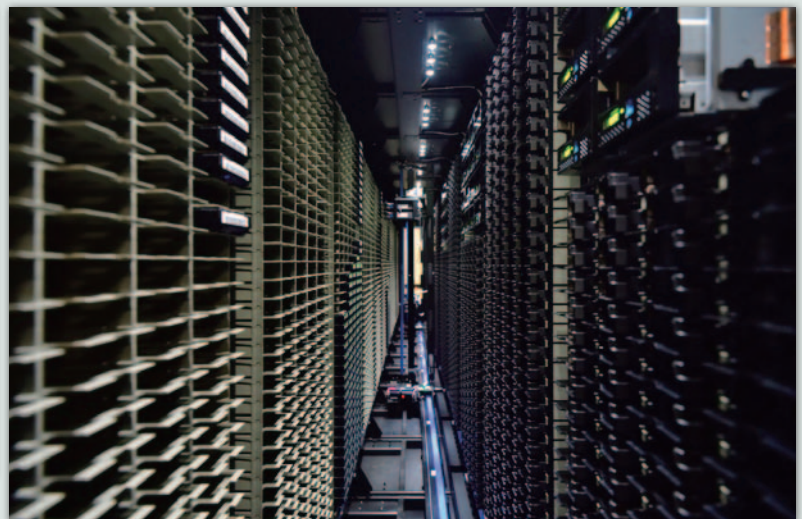


F5 BIG-IP Local Traffic Manager / WAF  
Lenovo SR650 / SR630  
IBM Storwise V5030E  
IBM System Storage TS4300

## Tape Library



IBM TS4500 Tape Library (100PB)

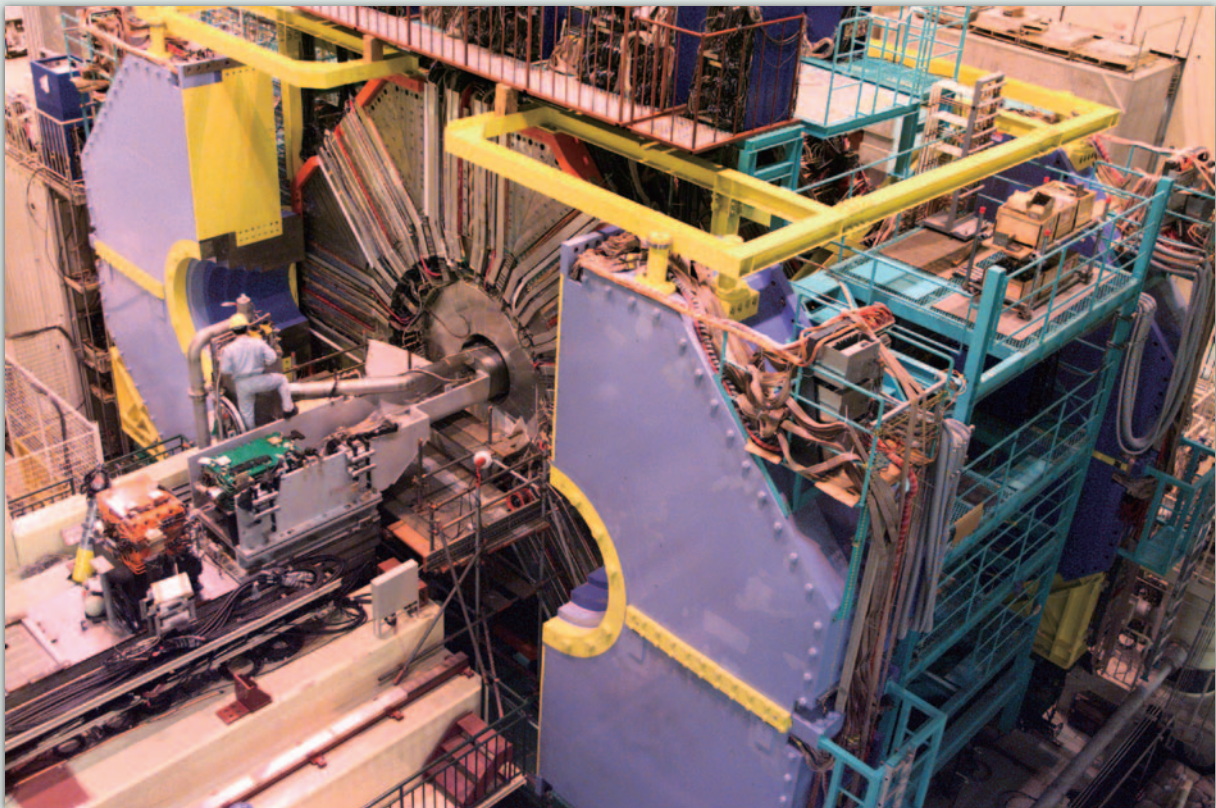




# User Groups of the Data Analysis

## Belle/Belle II Experiment

The Belle experiment is conducted to detect small differences among the reactions between matter and antimatter in B meson decays. It contributes to verification of the Kobayashi Maskawa theory, for which Kobayashi and Maskawa were awarded the Nobel Prize in Physics in 2008. The next generation of the Belle experiment, Belle II, will detect data 50 times as large as the Belle experiment.



Dr. Makoto Kobayashi and Dr. Toshihide Maskawa



The Nobel Prize medal awarded to Makoto Kobayashi, Professor Emeritus of KEK



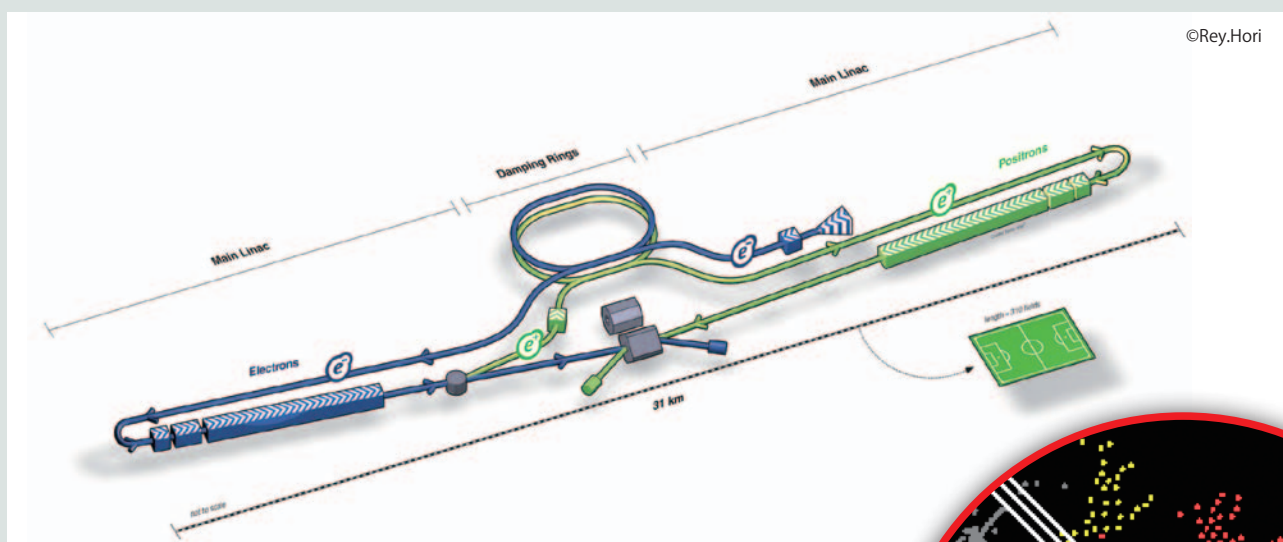
# System

## Tokai-to-Kamioka (T2K) Experiment

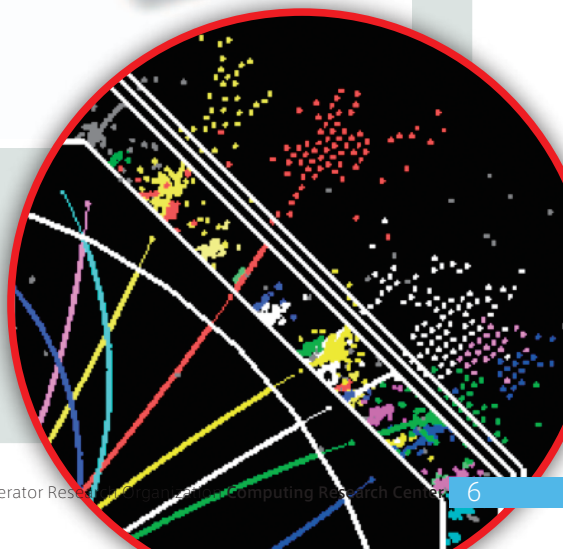
The objective of the T2K neutrino oscillation experiment is to elucidate the entire aspects of the origin of a neutrino's mass and neutrino oscillation (mixing). In the experiment, a beam of high-intensity muon neutrinos produced at the J-PARC accelerator in Tokai travels 295 km to the Super-Kamiokande located 1,000 m below the town of Kamioka in Gifu. As the neutrinos travel underground, they change flavors. This phenomenon is called neutrino oscillation (mixing). Detailed and comparative analyses of observation results between J-PARC and Super-Kamiokande are used in this experiment.



## International Linear Collider (ILC) Project



Consisting of two linear accelerators that face each other, the ILC would collide electrons with positrons at a collision energy of 250 GeV. Each collision creates many particles that enable us to examine the Higgs particle and to search for new particles such as dark matter. The international team is making an effort for realization of the ILC.



# Grid System

Accelerator physics experiments, such as Belle II, T2K, and ILC, collect the order of hundreds of petabytes data these days. KEKCC has introduced a system for the high-speed data share among collaborating institutes around the world, as well as the Grid system for the efficient and safe use/operation of the computer system even in environments where data is distributed globally.

## Grid Middleware

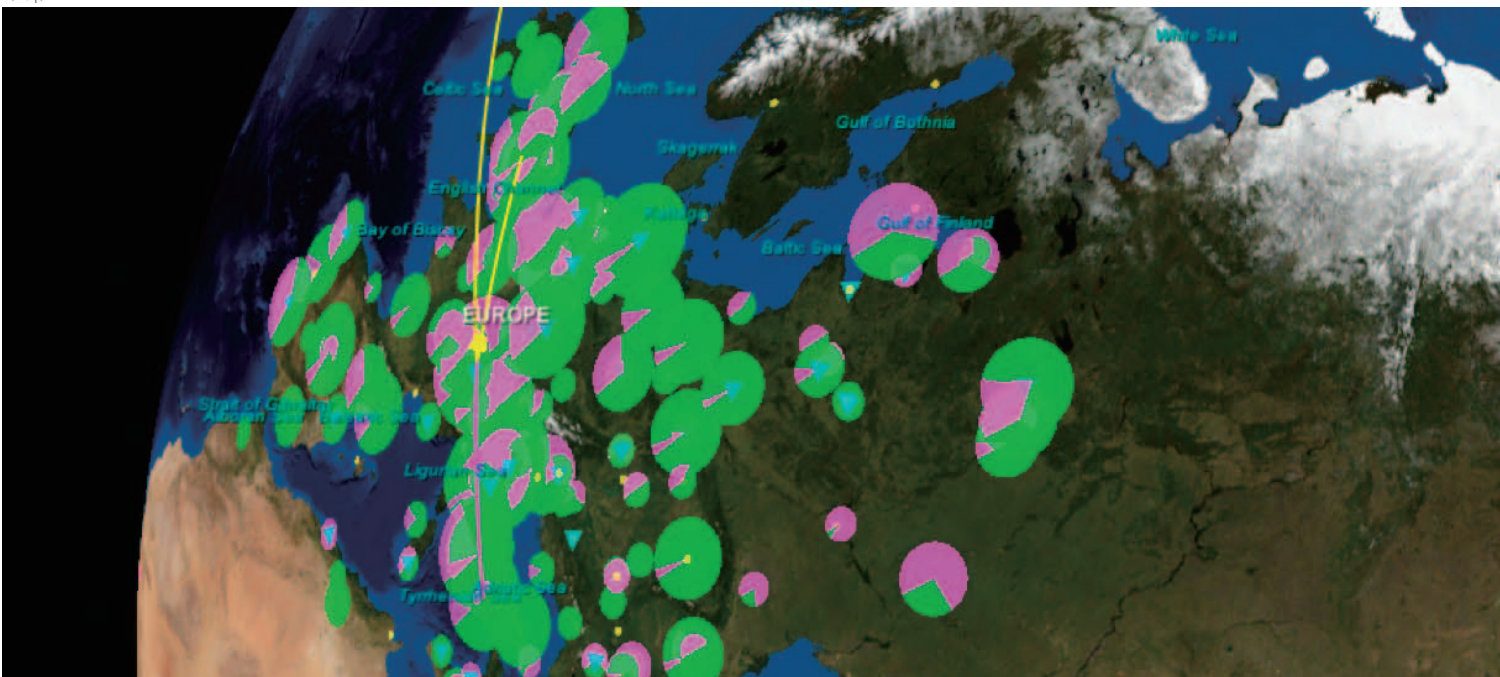
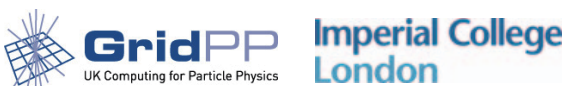
The software for the distributed systems is usually called Middleware, particularly in Grid computing. The Grid System in KEKCC consists of two types of middleware: Integrated Rule-Oriented Data System (iRODS) and Unified Middleware Distribution (UMD).

### Integrated Rule-Oriented Data System (iRODS)

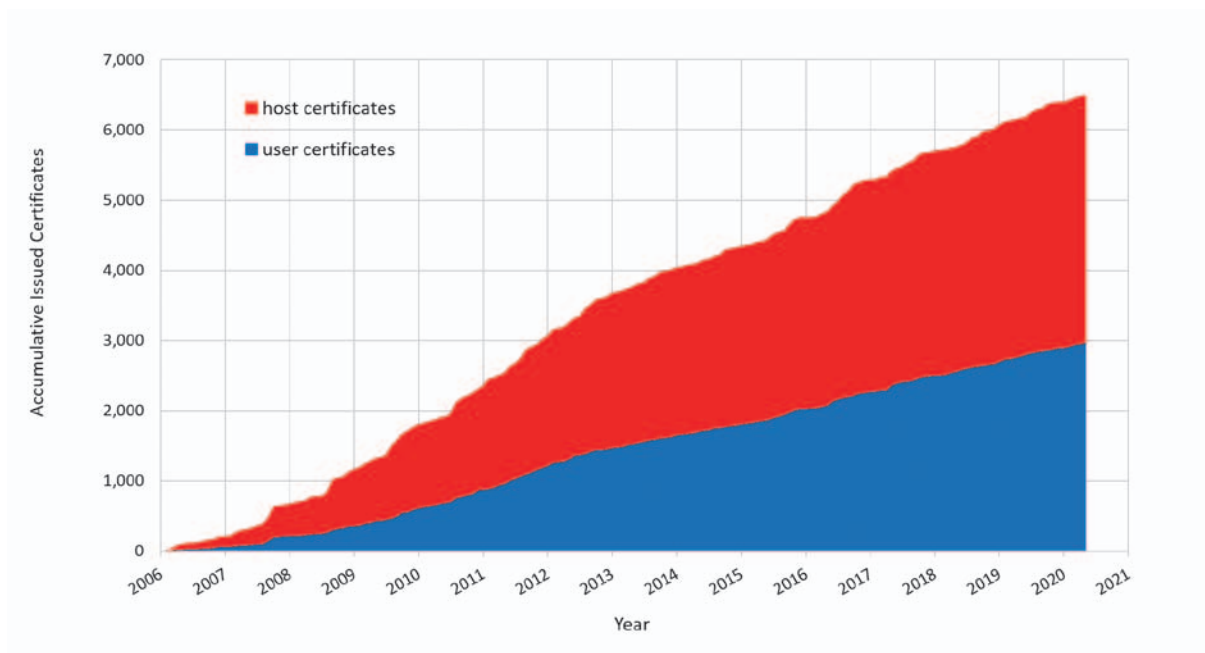
iRODS is a software specialized for the data sharing. It is actively utilized to transfer data produced in J-PARC (KEK Tokai Campus) to KEKCC (KEK Tsukuba Campus).

### Unified Middleware Distribution (UMD)

UMD is the integrated set of various middleware deployed in the KEKCC Grid System. It enables not only for the data sharing but also transparent use of distributed computing resources. UMD is widely used in the Worldwide LHC Computing Grid (WLCG), the world's largest computing infrastructure. A lot of accelerator physics experiments, including LHC, Belle II, and ILC, are designed to analyze the huge amounts of data leveraging that computing infrastructure.



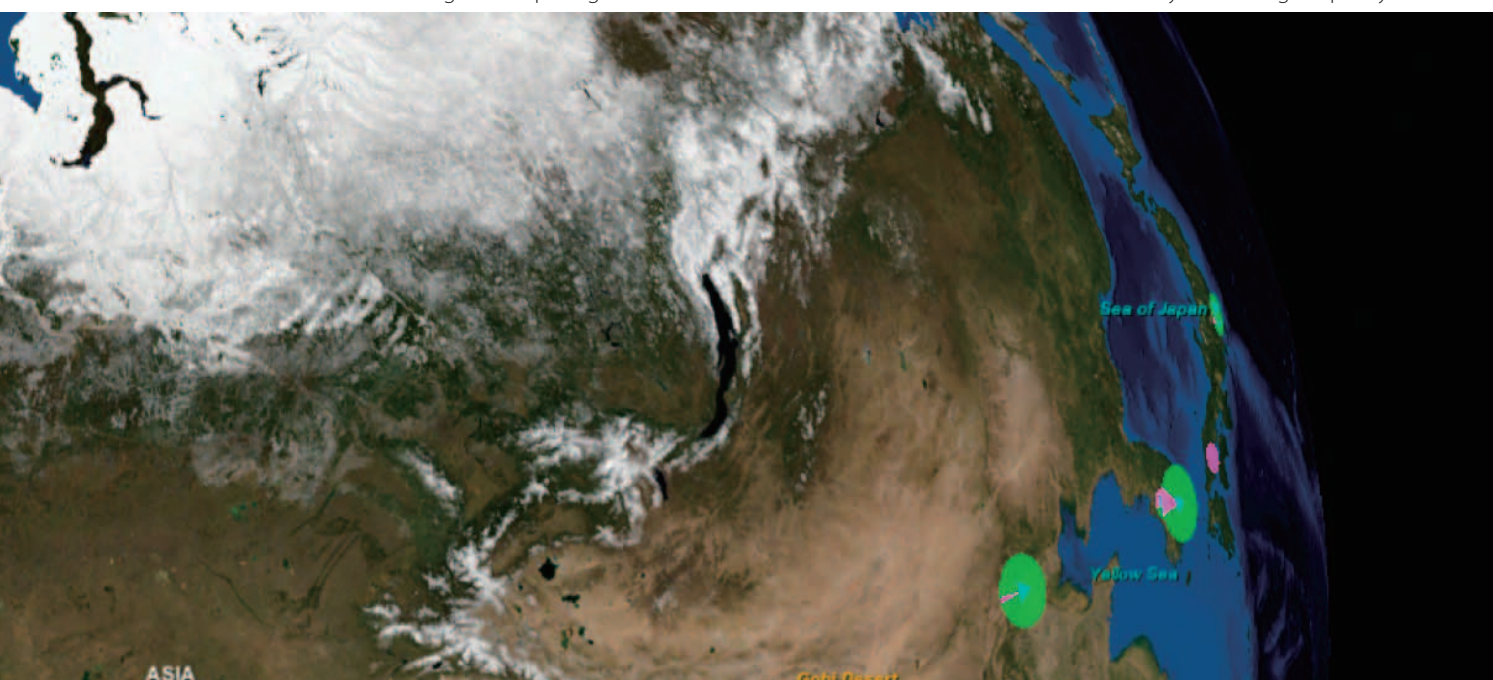




## Certificate Authority

We have maintained a certificate authority since 2006 to support various projects using grid computing conducted at KEK and in Japan, such as the Belle experiment at KEK, the ATLAS and ALICE experiments at CERN, the ILC project, and lattice Quantum Chromodynamics (QCD). Our certificate authority is an accredited member of the International Grid Trust Federation (IGTF), which plays a major role in establishing an authentication infrastructure for international large-scale computing grids. The certificate authority issues digital certificates, using SHA-2 signature algorithms, to users and hosts. The issued certificates and associated keys are used for grid authentication and secure communication. The server of the certificate authority distributes a Certificate Revocation List (CRL) and operates the Online Certificate Status Protocol (OCSP) responder, with an IPv4/IPv6 dual-stack solution.

WLCG – the world’s largest computing infrastructure – consists of 1 million CPU cores and 1 exabyte of storage capacity as of 2016.



# Supercomputer System

The KEK Supercomputer System is used for large-scale numerical simulations. The current system is NEC SX-Aurora TSUBASA. The system is provided for researchers under “Particle, Nuclear, and Astro Physics Simulation Program” promoted by Institute of Particle and Nuclear Studies (IPNS), KEK.

## NEC SX-Aurora TSUBASA



NEC SX-Aurora TSUBASA is a heterogeneous system equipped with the vector engines that accelerate arithmetic operations. The large memory bandwidth of the vector engines is particularly efficient for large-scale numerical computations.

System: NEC SX-Aurora TSUBASA  
A500-64 2 rack

Number of vector hosts: 16

Number of vector engines: 128

Total peak performance: 313.6 TFlops  
(double precision)

Total main memory: 6 TB

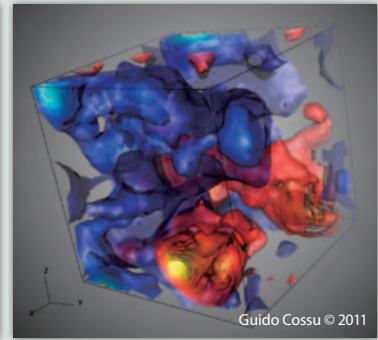
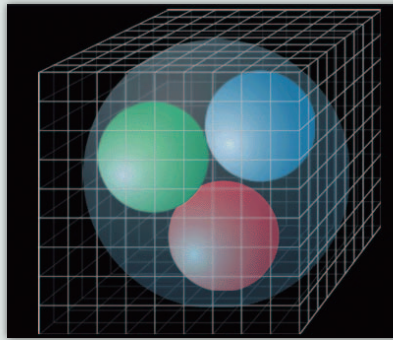
\*1: Flops (Floating point operations per second) is a measure of the performance on four arithmetic operations in a second. G (giga), T (tera), and P (peta) represent 10 to the power 9, 12, and 15, respectively.



# Scientific Research on the Supercomputer System

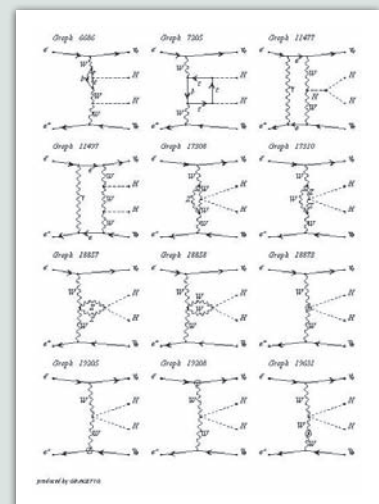
## Lattice Quantum Chromodynamics

The dynamics of quarks and gluons, which are elements of nucleons, are described by Quantum Chromodynamics (QCD), the fundamental theory of the strong interaction. Numerical simulations of QCD have become possible with lattice discretization of four-dimensional space-time. It enables prediction of the masses and decay form factors of nucleons and mesons, and exploration of vacuum structures without model assumption.



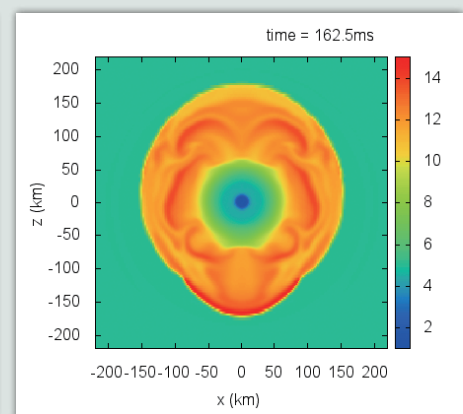
Numerical simulations on supercomputers can elucidate various characteristics of particles and atomic nuclei that are intractable by analytical calculation. These characteristics include the following:

- Automated computation of reaction processes of particles
- Quantum chromodynamics at finite temperature/density
- Space-time reduced models of the gauge theory
- New approaches to understand structure of field theories



## Simulation of Supernova Explosions

The mechanism of a supernova explosion caused by gravitational collapse of a massive star is still shrouded in mystery. KEK seeks to solve this mystery by means of large-scale simulations incorporating the neutrino effect that plays an essential role in the explosion mechanism.



# HPC Servers for Joint / Collaborative Research

KEK is engaged in the development of a next-generation architecture and corresponding applications to exploit the maximum performance of the architecture.

## Suiren2 and Suiren Blue

The Suiren2/Suiren Blue systems are supercomputers equipped with many-core Pezy-SC processors (by Pezy Computing K.K.) in a compact manner via a submersion liquid cooling technology that enables low power consumption and high-density mounting, which was developed by ExaScaler Inc. KEK is engaged in the development of high-performance applications in collaboration with Pezy/ExaScaler.

### Suiren (Water Lily) 2 : "ZettaScaler-2.2" 12 Bricks

- Total peak performance: 1,082 TFlops
- Main memory: 26 TB (2-TB CPU + 24-TB Pezy-SC2)
- 384 Pezy-SC2 processors

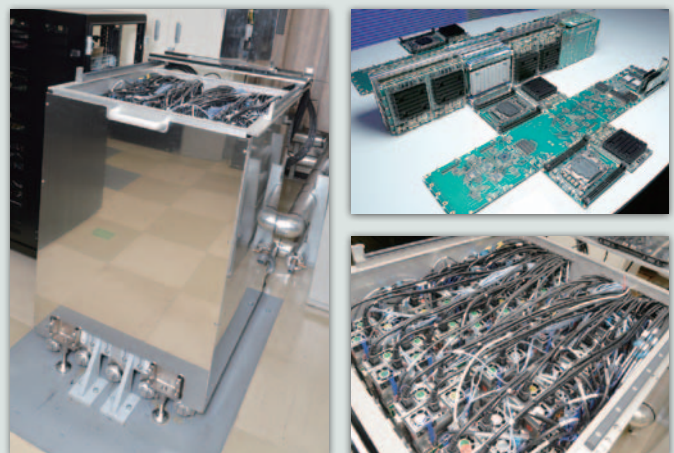
Because high-performance computers generate significant quantities of heat, an efficient cooling method is key for their optimization and downsizing. Suiren can be efficiently cooled by complete immersion in a special coolant. Suiren needs neither air-cooling fans nor water-cooling tubes, and therefore saves space. Suiren was upgraded to Suiren2 by installation of new Pezy-SC2 processors.



### Suiren Blue (Blue Water Lily) : "ZettaScaler-1.5" 16 Bricks

- Total peak performance: 428.3 TFlops
- Main memory: 16 TB (8-TB CPU + 8-TB Pezy-SC)
- 256 Pezy-SC processors

Suiren Blue gives the same arithmetic performance as Suiren, but it is a more compact implementation that occupies a quarter of the installation area and consumes even less power than Suiren.



Suiren Blue and Suiren2 achieved the world's second ranks, respectively, in "The Green 500 List" of supercomputer power consumption performance ranking published in July 2015 and in November 2017.



# Data Grid for Computational Physics

## Japan Lattice Data Grid (JLDG)

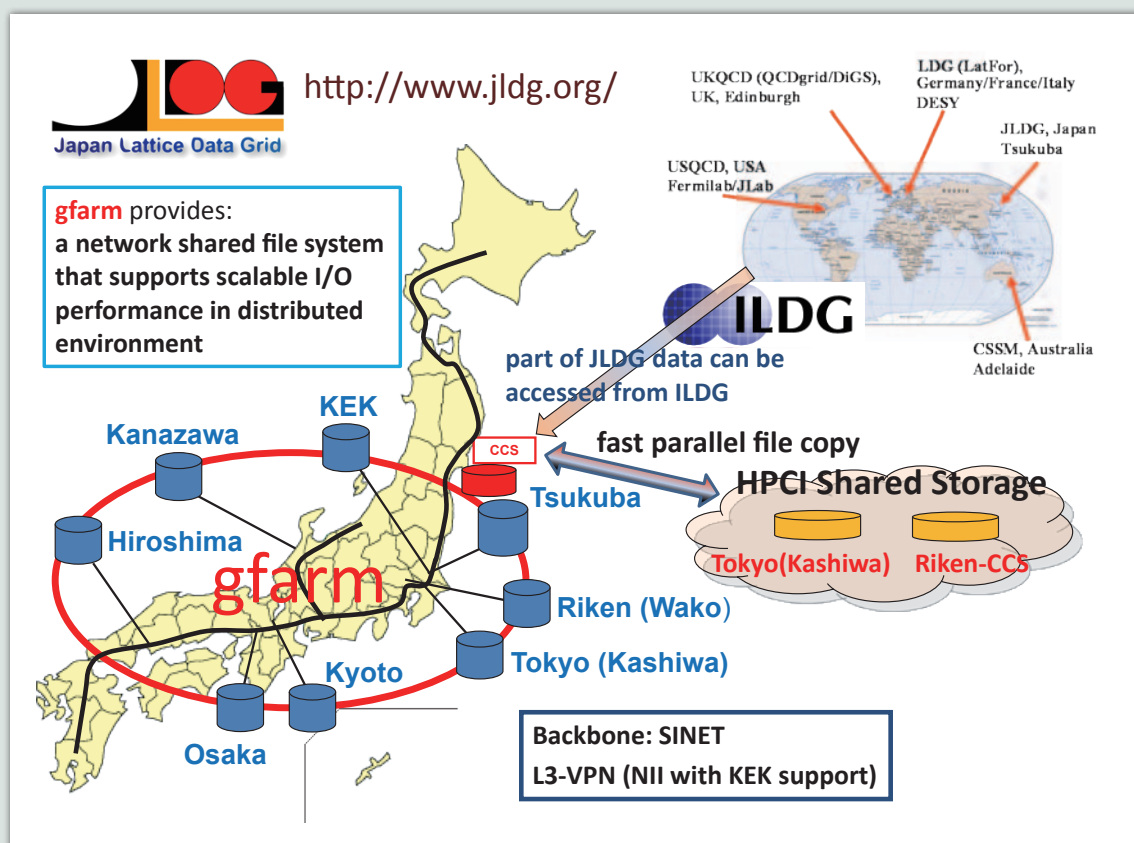
Lattice QCD simulations produce large amounts of data. To analyze these data using supercomputers across Japan, it is necessary that the data be transferred at a high speed and handled as if they are on a single file system.

JLDG is a data grid for computational particle physics, which is constructed on the high-speed network SINET, operated by the National Institute of Informatics. It uses Gfarm, a grid file system developed by the National Institute of Advanced Industrial Science and Technology in cooperation with University of Tsukuba.

Status in May 2020:

13.0 PB total storage, 12.3 PB used (95 %)

141M files



# KEK Network

KEK is connected to SINET, an academic network by 120 Gbps bandwidth including backup circuit. Most of the devices in KEK are connected via 1Gbps link, but some systems that require high-throughput network are connected to core switches via multi links of 10Gbps.

There are about 210 buildings in campus, and 50 of them are directly connected to the Computing Research Center (CRC) through optical fibers. In the case of populous building, each floor is directly connected to CRC.

These optical fibers are connected to authentication switches that manages connections to network outlets in each room. The authentication switch automatically connects devices to proper networks using the network registration database. Unregistered devices can't use our campus network.

There are about 250 wireless network access points in Tsukuba Campus, and these are controlled centrally. Each access point services four different networks and user can choose one of them according to their needs.

## Wavelength division multiplex



XGMC2016

## Border switch



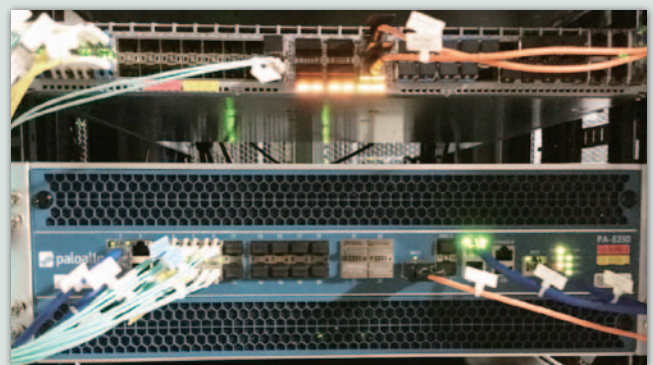
Brocade MLXe4

## Core switch



Nexus9508

## External router Firewall



External router: ARISTA 7280SR  
Firewall: Paloalto 5250



Researchers in high-energy physics have collaborated over international networks since the 1970s. Although the wide spread of the internet has changed applications and technology for them, their aims are still data transfer and communication such as teleconference and e-mail. The KEK network has 10 Gbps redundant bandwidth firewalls for high-speed data transfer.

## LHCONE

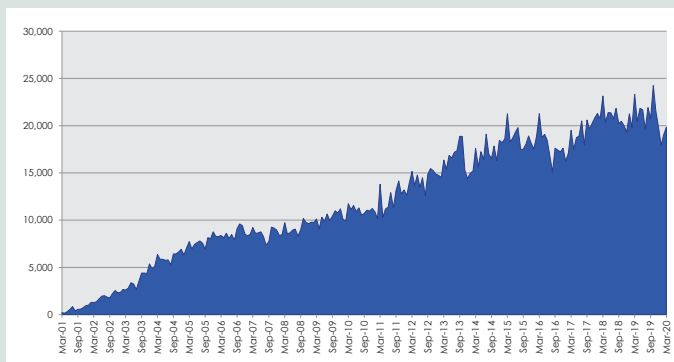
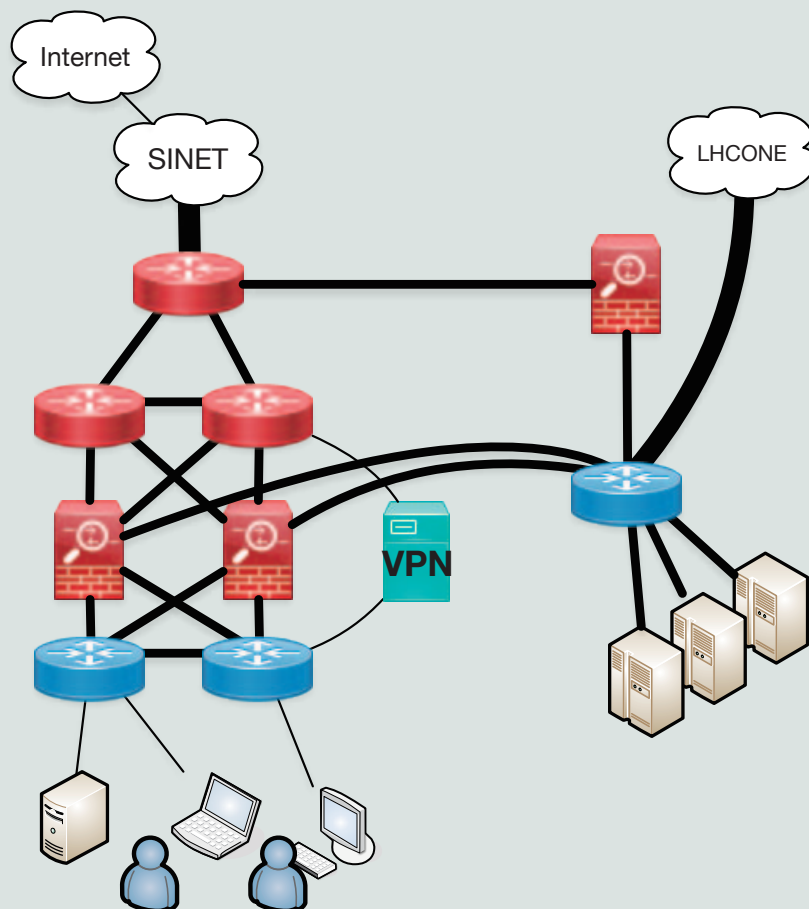
The LHC experiment at CERN produces extremely large amounts of data, and those data are processed by distributed computing. LHCONE is a closed network specialized for mass data transmission among LHC grid computing sites. As most of the grid computing sites joining the Belle II experiment in KEK are already connected to LHCONE, KEK is also connected.

## KEKCC

The KEKCC system operated by CRC has a firewall that is independent of the campus network at KEK because KEKCC provides high-speed data transfer not only for KEK staff, but also for collaborators at remote sites. This dedicated firewall enables high-speed data transfer using the grid middleware of up to 20 Gbps.

## VPN

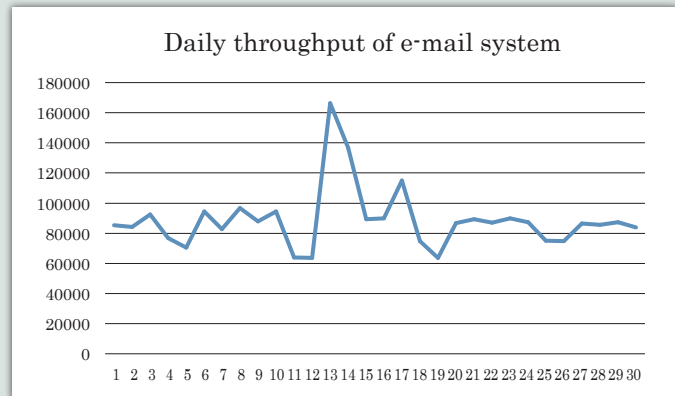
CRC has provided a Virtual Private Network (VPN) connection service since 2001. The firewall prohibits any access from the internet to servers in the KEK campus network, except to servers in the demilitarized zone(DMZ) network. May researchers at KEK have their own servers on the KEK campus network; the VPN enables access to those servers from the internet. The number of VPN connections has increased annually, and currently there is close to 20,000 connections a month.



# IT Service

## E-mail

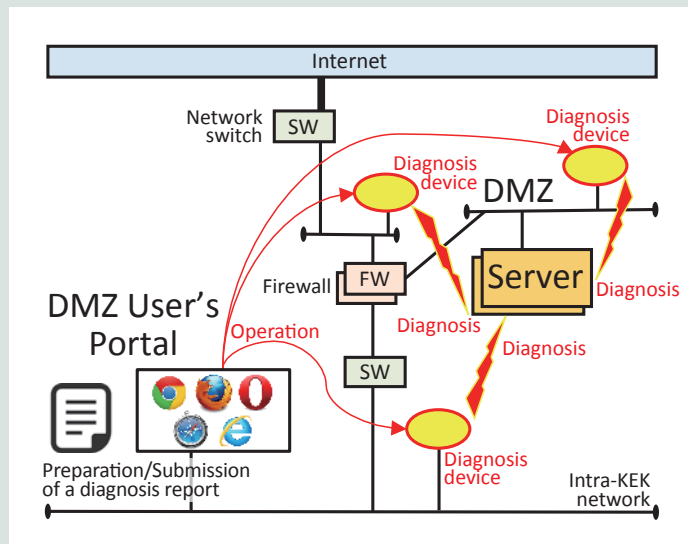
The e-mail system sends and receives e-mails for more than 1,600 persons at KEK. The system also operates over 900 mailing lists associated with research activities and operations at KEK. The figure shows the daily throughput of our e-mail system in April 2020. It deals with approximately 100,000 e-mails per day and has enhanced security measures for dealing with spam and computer viruses.



## The DMZ User's Portal: A vulnerability management portal

Servers receiving access from outside KEK, such as internet connections, are required to maintain a high security level. In KEK, those servers are connected to the DMZ network.

CRC developed a vulnerability\* management portal, called the DMZ User's Portal, to provide a vulnerability management environment for managers who have their servers in the DMZ. The portal site is linked to the vulnerability diagnosis devices and other systems to provide a variety of security services on DMZ. Server managers can not only confirm periodic vulnerability diagnosis reports for security maintenance but also can prepare and submit self-assessment reports of security inspection conducted by KEK.



\* Vulnerability refers to a defect in information security that developed owing to program malfunction and/or design error in the computer OS and/or software. A vulnerability is also called a security hole. Using a computer that has a vulnerability can lead to unauthorized access to that computer and/or viral infection.



# Web System

The Computing Research Center provides the KEK official websites ([www.kek.jp](http://www.kek.jp), [www2.kek.jp](http://www2.kek.jp)) and the websites that support research activities at KEK. These websites include the research information web ([research.kek.jp](http://research.kek.jp)) to publish research activities and achievements, and Wiki ([wiki.kek.jp](http://wiki.kek.jp)) to provide a place for exchanging information between researchers. We operate the conference web system ([www-conf.kek.jp](http://www-conf.kek.jp), [conference-indico.kek.jp](http://conference-indico.kek.jp)) that supports the hosting of conferences and workshops and the publishing of results, and also the KDS system ([kds.kek.jp](http://kds.kek.jp)) that supports the group meetings.

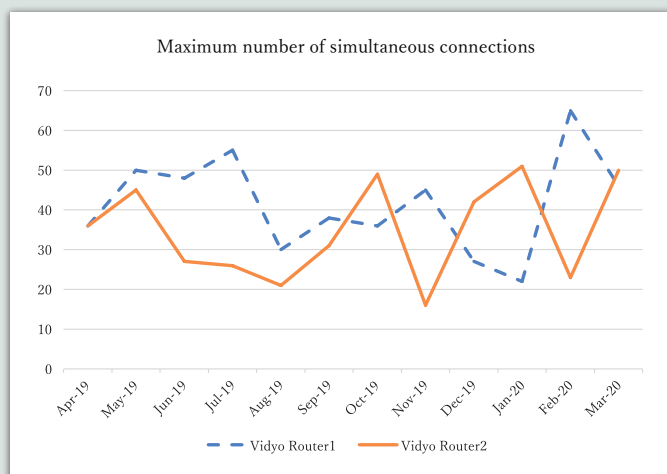


# Video Conference System

We have been providing a video conference service with an MCU in a multipoint videoconferencing system for more than 20 years. In October 2018, we have replaced an MCU with a new video conference service "Vidyo".

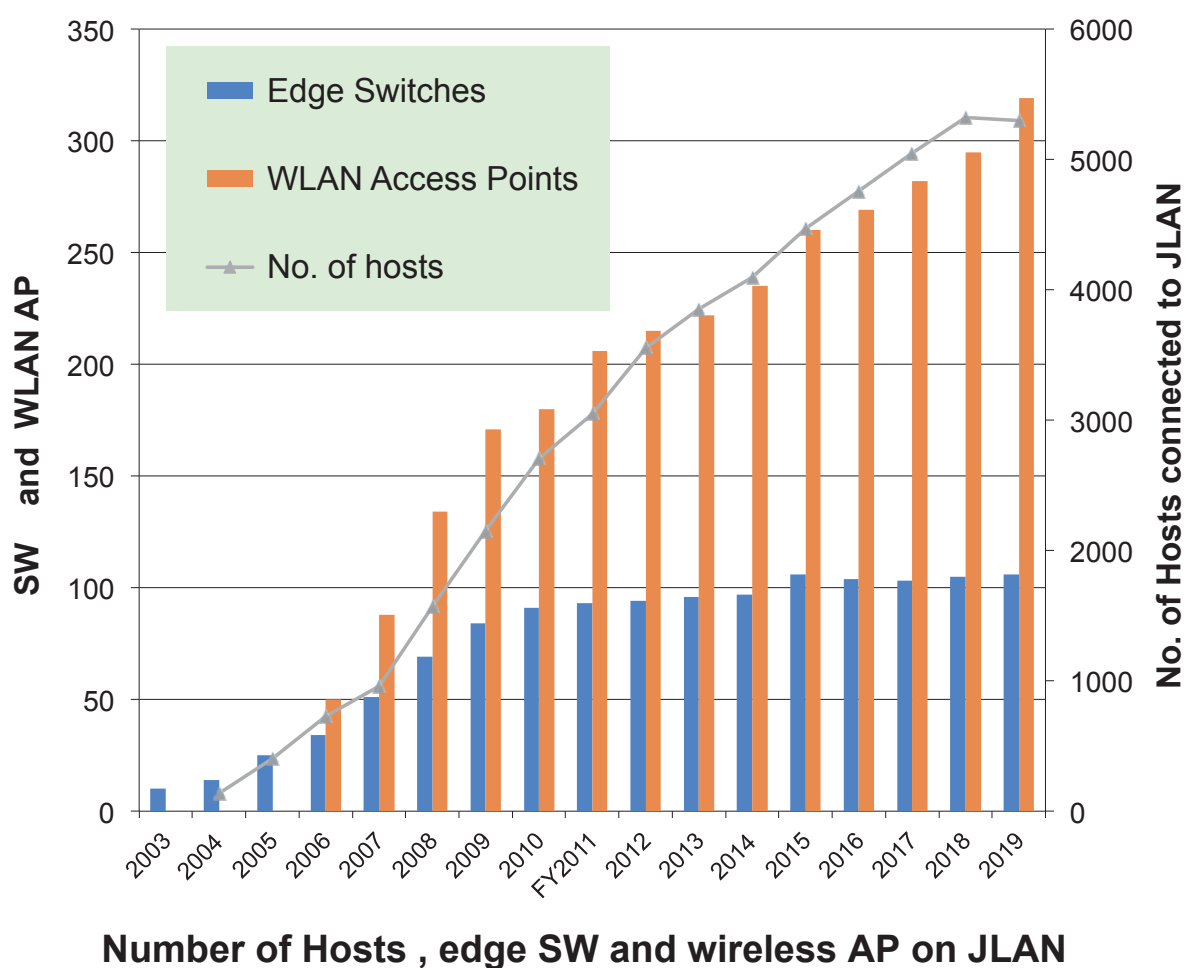
The client software "VidyoConnect" supports multi-platforms such as Windows, macOS, iOS, and Android. For Linux, we open a generic communication channel via WebRTC, which allows users to attend the video conference on common web browsers with no specific software.

The number of registered users reached nearly 1,200 in about 17 months after the service launched. The figure in the right shows the number of simultaneous connections to the system, which is load-balanced by two machines. Roughly 110 of connections is the upper limit in the current contract of the system. 70-90% of maximum capacity has been used for the last few months.

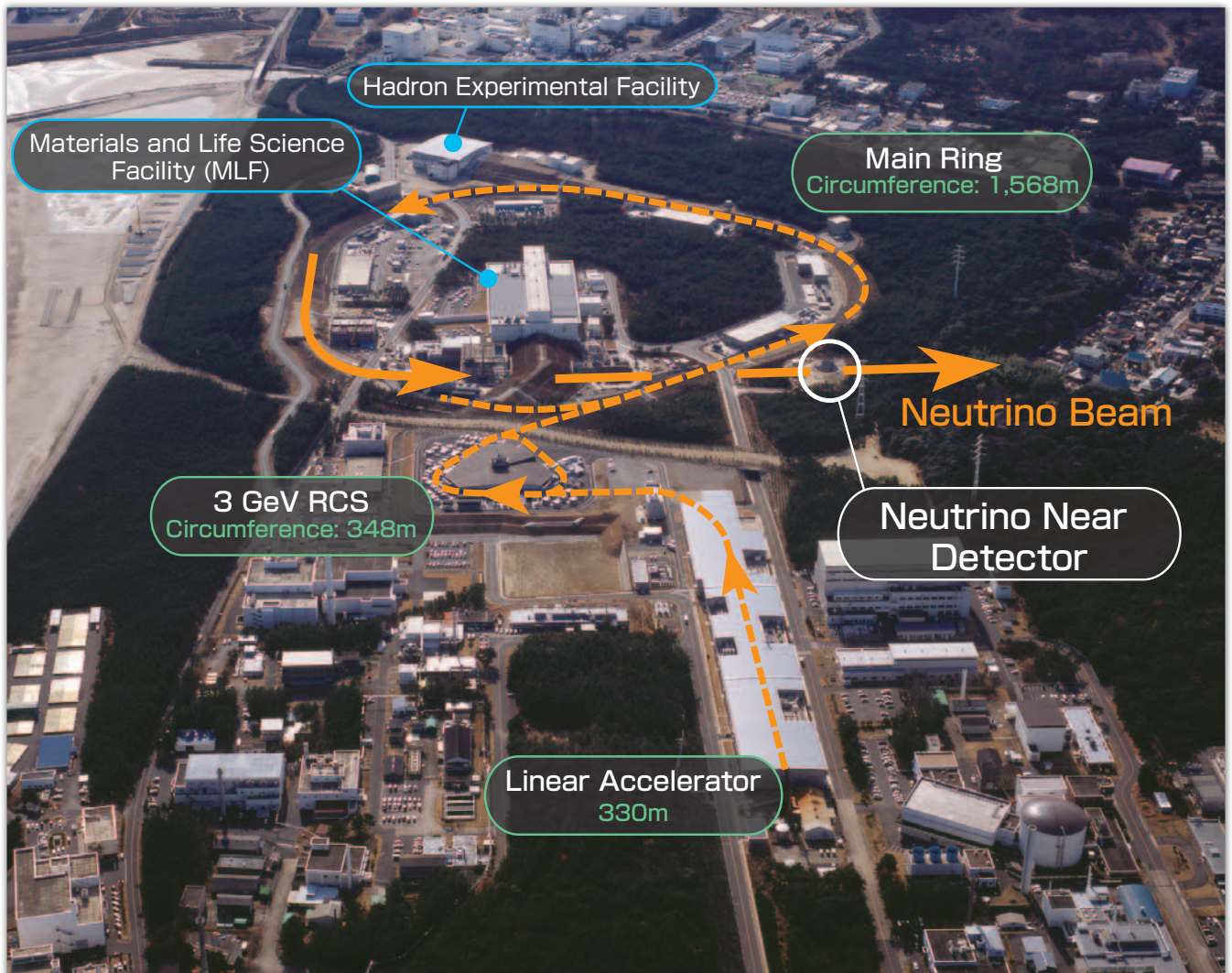


# J-PARC

The Japan Proton Accelerator Research Complex (J-PARC: <https://www.j-parc.jp>) consists of the main facilities on the Tokai Campus, and is run jointly by KEK and the Japan Atomic Energy Agency (JAEA). In J-PARC, which is a multi-purpose quantum beam facility open to users from around the globe, cutting-edge experiments and research are conducted. These experiments and research are across a wide range of scientific fields, including particle physics, nuclear physics, material science, life science, and nuclear technology, that make use of the variety of secondary-particle beams such as those of neutrons, muons, K mesons, and neutrinos produced by one of world's highest intensity proton beam. The J-PARC network infrastructure, JLAN, connects more than 5,000 information systems in J-PARC, providing a LAN environment and an internet access speed of 10 Gbps. It also connects the Tokai area, where accelerators exist, to the Tsukuba area, where the main data analysis computers exist, supporting research activities at J-PARC. The internet and Tokai-Tsukuba connections use SINET (<https://www.sinet.ad.jp>), which is provided by the National Institute of Informatics.



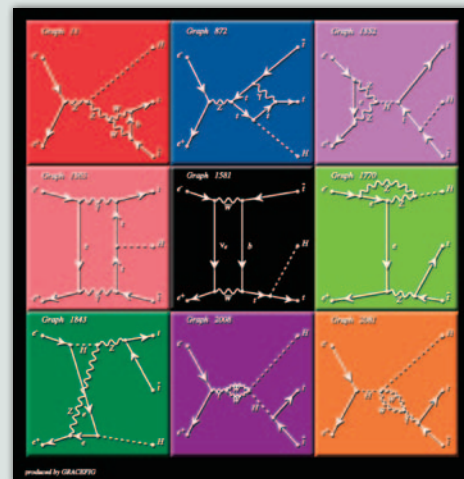




# Research Activities

## GRACE

GRACE is a software system for automatic computation of scattering cross section in particle physics. It was developed collaboratively by theoretical, experimental, and computer specialists. The system is not only used for precise theoretical particle physics analysis but also utilized for high-energy physics experiments through creation of programs for event generators to analyze experiments. By utilizing software technologies such as numerical computation techniques including integration, formula manipulation techniques for dealing with Feynman diagrams, and program/parallelization techniques for high-speed computation, as well as a system dedicated to high-speed multiple-precision calculation, this system continues to provide the high-speed, precise, and large-scale computing required for the ILC.



## Manyo-Lib: Analysis software framework for neutron scattering experiments

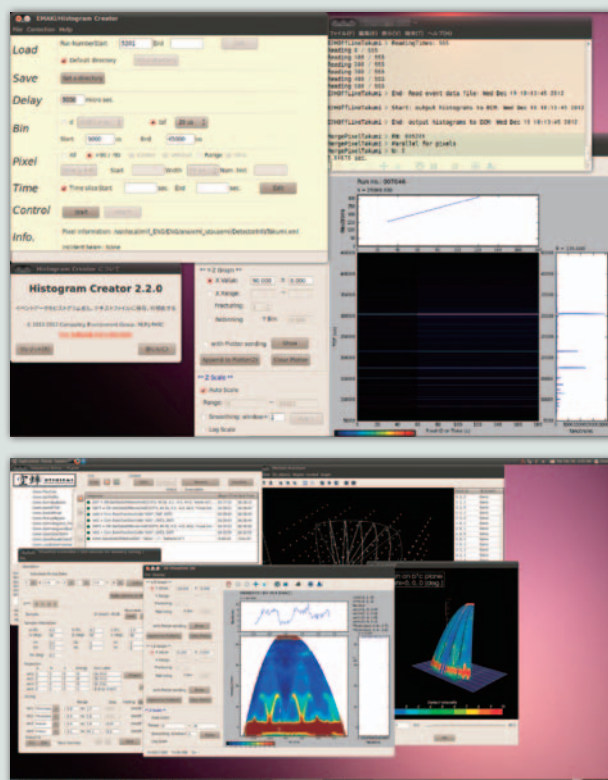
"Manyo-Lib" is a software framework for developing analysis software at the Materials and Life Science Facility (MLF) in J-PARC. MLF provides one of the most intense pulsed neutron and muon beams for various materials and life sciences experiments.

Manyo-Lib comprises a C++ class library with a python interface, and provides data analysis operators, data containers, network distributed data processing modules, user interface modules, etc.

Manyo-Lib has been applied to develop data analysis environments operating on 20 neutron scattering instruments in MLF. The figures presented are screenshots of these instruments.

The user manual and the source code of Manyo-Lib can be obtained at its web page:

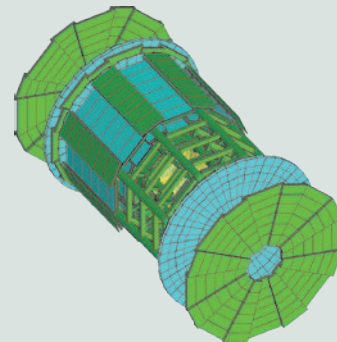
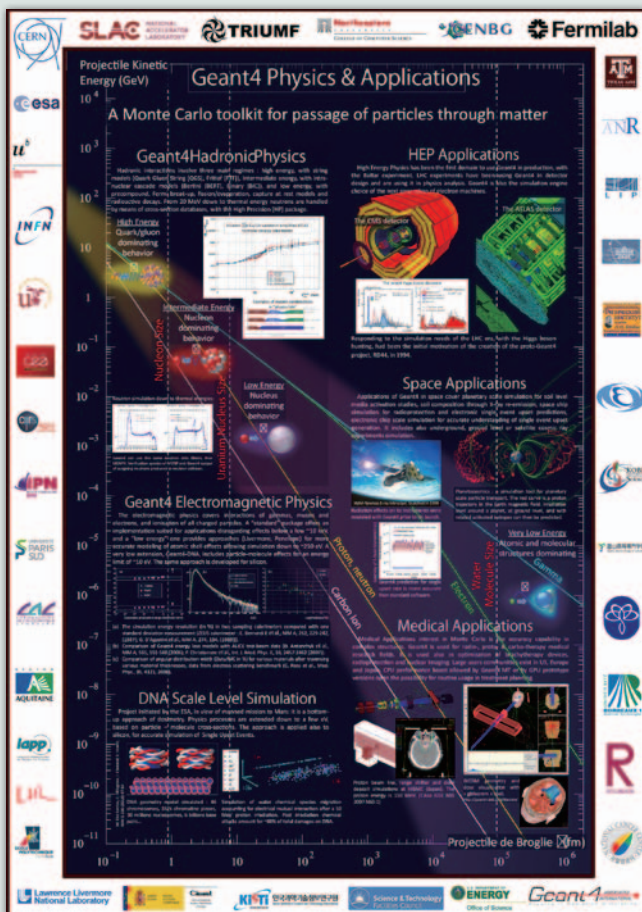
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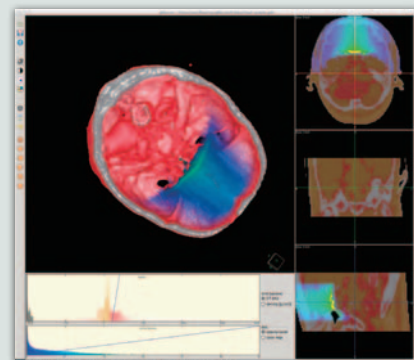


# Geant4

Geant4 is software for simulation of the interactions between elementary particles and materials in high-energy physics experiments. It is developed and maintained under the international collaboration. Geant4 is widely used in other fields such as medicine and astronomy. CRC collaborates with medical users and extends Geant4 applications to the simulation of particle therapy.



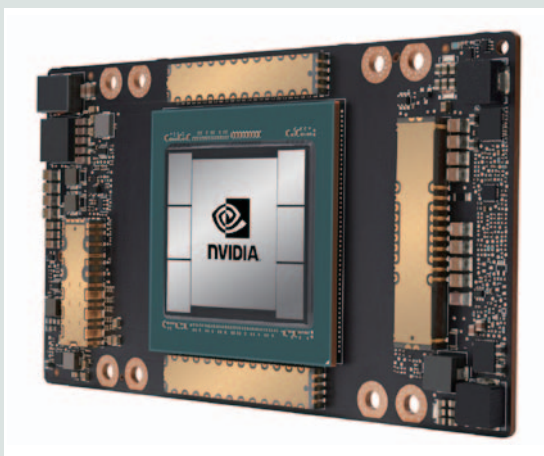
DAWN: Software for high-quality rendering of detectors and particle trajectories. The figure shows ATLAS detector.



Opacity curve and color map editor

gMocren: Visualization of CT-scanned images and simulation result.

# MPEXS



NVIDIA A100 GPU

The graphic processing unit (GPU) is generally used for computer graphics. It is a particular device that has several thousands of parallel-processing cores. In recent years, different scientific applications, including AI, make big leaps in accelerating applications using GPU as general-purpose processors. CRC is developing a GPU-based radiation simulator called "MPEXS." The main target of MPEXS in the fields of medicine and biology. Taking advantage of GPU's high computing power, we work on the acceleration of treatment planning in particle therapy and the study of biological effect by radiation. So far, we realize 400x speed up comparing Geant4 simulation. In the future, we plan MPEXS extensions to the simulation in high-energy physics.

<https://www.kek.jp>



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