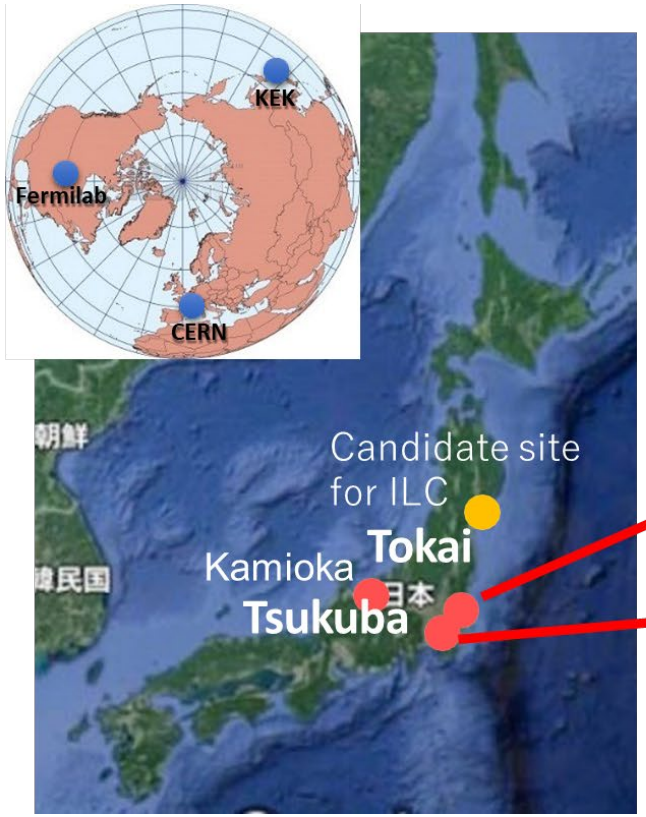
KEK and CRC status and perspective

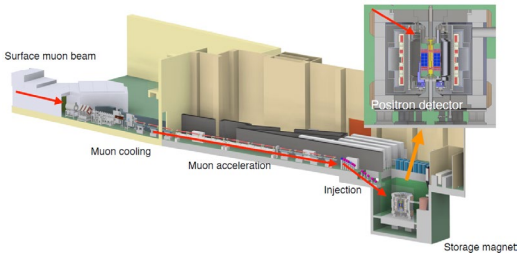
Tomoaki Nakamura
on behalf of KEK Computing Research Center

Accelerator science at KEK

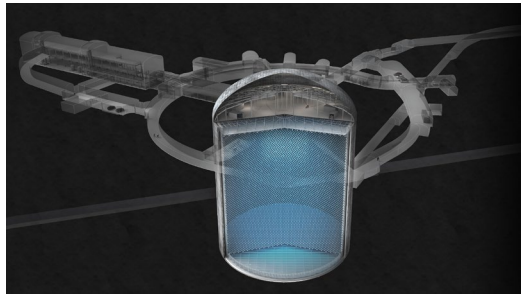


KEK covers diverse field of accelerator based science making full use of the electron machines in Tsukuba and the proton machines in Tokai.

Muon g-2/EDM



Hyper-Kamiokande



J-PARC

- Hadron hall: Particle and nuclear physics experiments with fixed target.
- Neutrino facility: Neutrino beamline for T2K and upgrade program for Hyper-Kamiokande, COMET.
- MLF: Material and life science experiments with neutron and muon probes. Muon g-2/EDM experiment will be done at MLF.

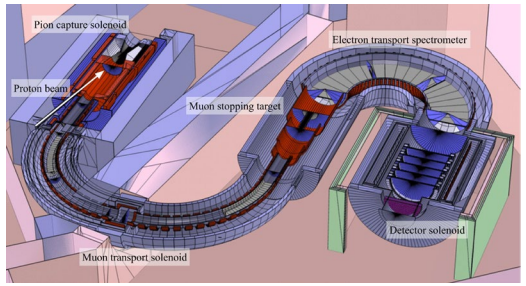
SuperKEKB/Belle II

- Asymmetric e+e- collider at Υ(4s) with target L=8x10^{35}/cm^2/s.
- ~10^{11} *B*, *D* and *t* measured with vertex reconstruction and PID.
- Physics run started March 2019.
- Belle II collaboration consists of 1000 physicists from 26 countries.

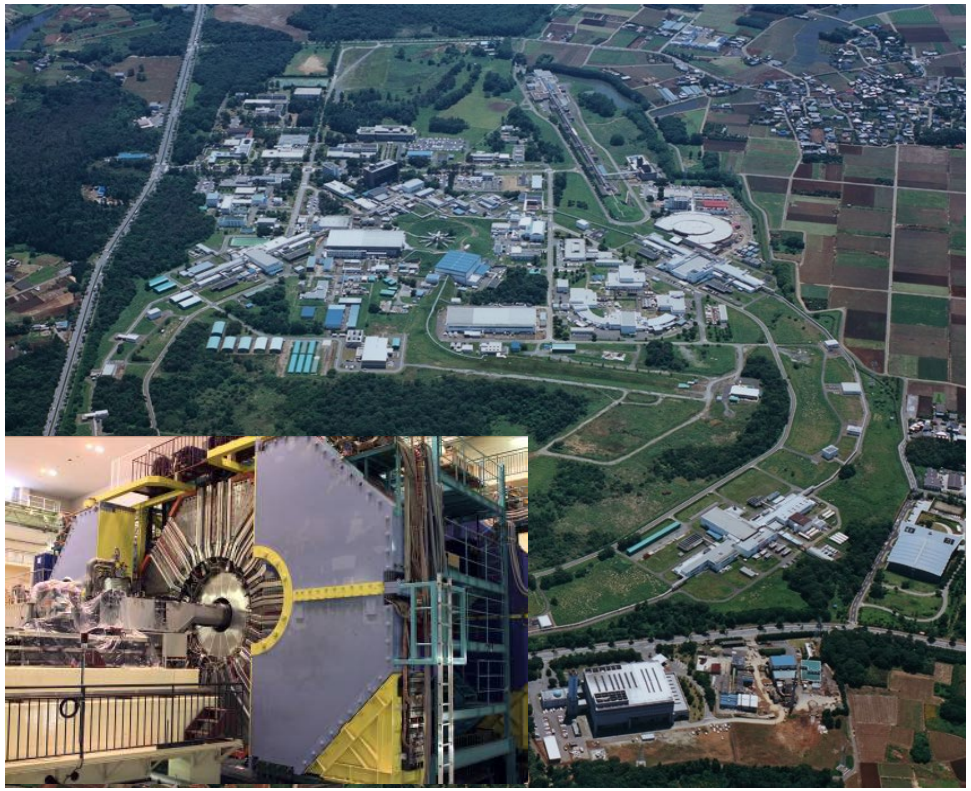
R&D

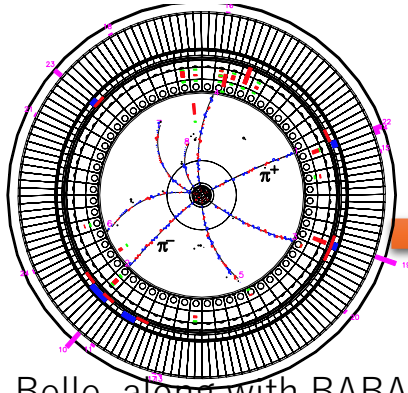
- ILC: Technical development and efforts to realize it
- Contributions to HL-LHC and ATLAS upgrade

COMET



Particle physics: SuperKEKB and Belle II



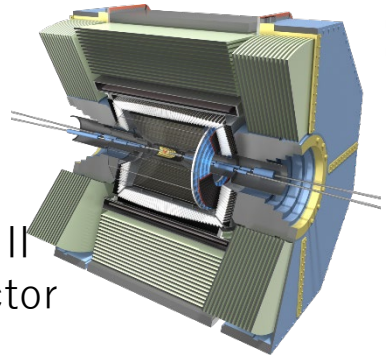


Dr.Kobayashi Dr.Maskawa

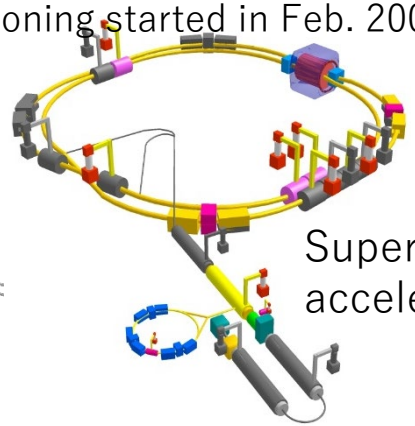
Belle, along with BABAR/SLAC, discovered CP violation in B mesons, and confirmed Kobayashi-Maskawa theory.

The apparatus is now being upgraded to search for new physics beyond this theory.

Accelerator commissioning started in Feb. 2006.



Belle II detector

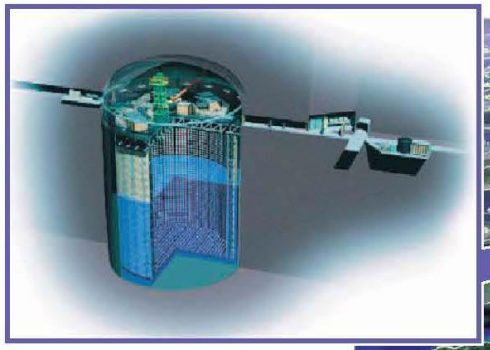


SuperKEKB accelerator

~750 scientists from 25 countries

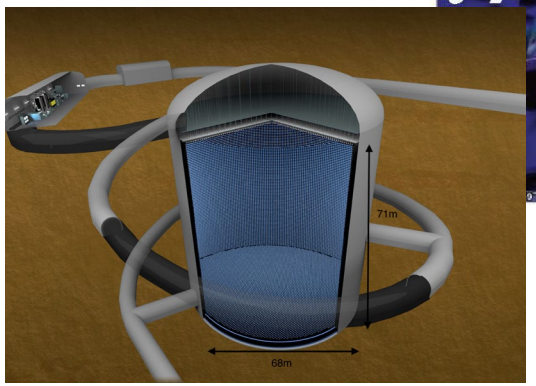
Neutrino physics: Tokai to Kamioka (T2K)

2010~ (Running)



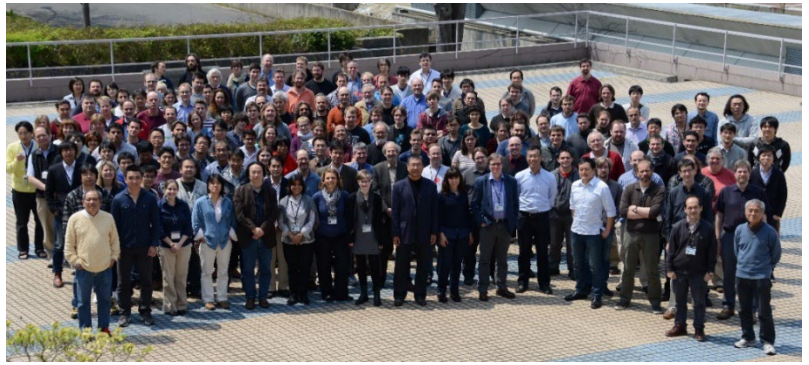
Super-Kamiokande
(ICRR, Univ. Tokyo)

J-PARC Main Ring
(KEK-JAEA, Tokai)



Hyper-Kamiokande
x10 larger than SK
Under construction toward
physics data taking in 2027

T2K collaboration
~500members from 63 institutes in 11 countries

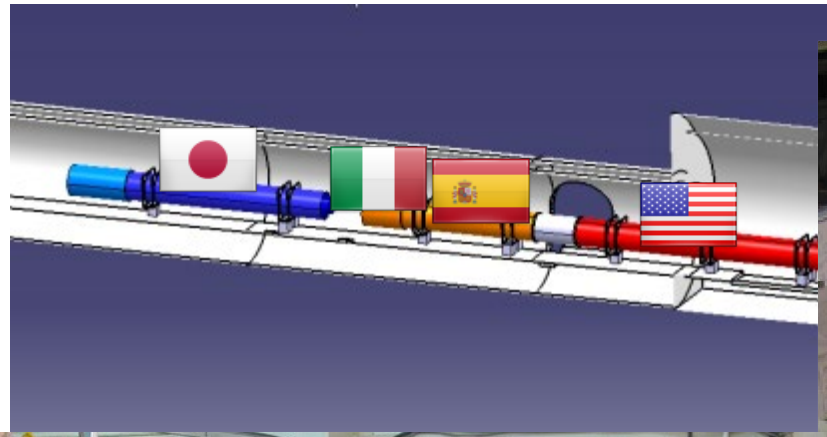


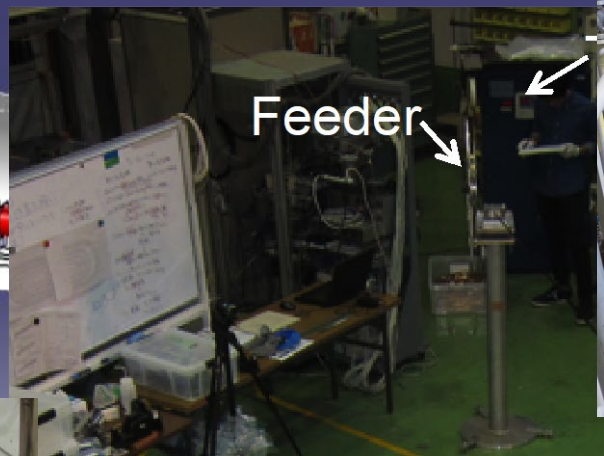
- High intensity ν_μ beam from J-PARC MR to Super-Kamiokande
- Observation of $\nu_\mu \rightarrow \nu_e$ (2013)
- Updated goals
  - Precise measurement of ν_e appearance
  - Precise measurement of ν_μ disappearance

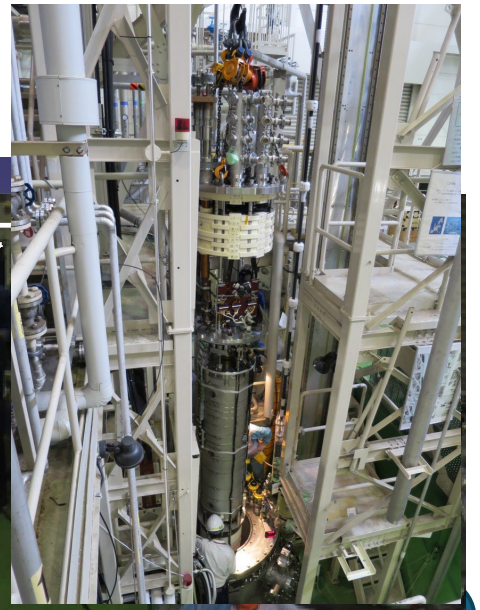
  ➔ CPV phase, contribution to mass hierarchy determination

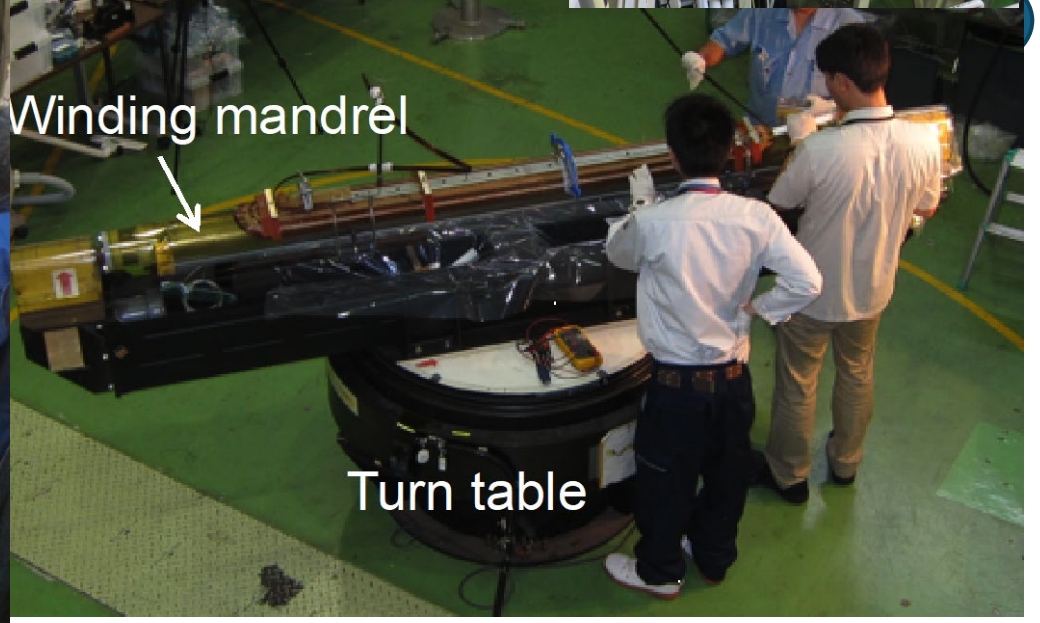
Contribution to the LHC and ATLAS experiment

2m Model coil production and test at KEK



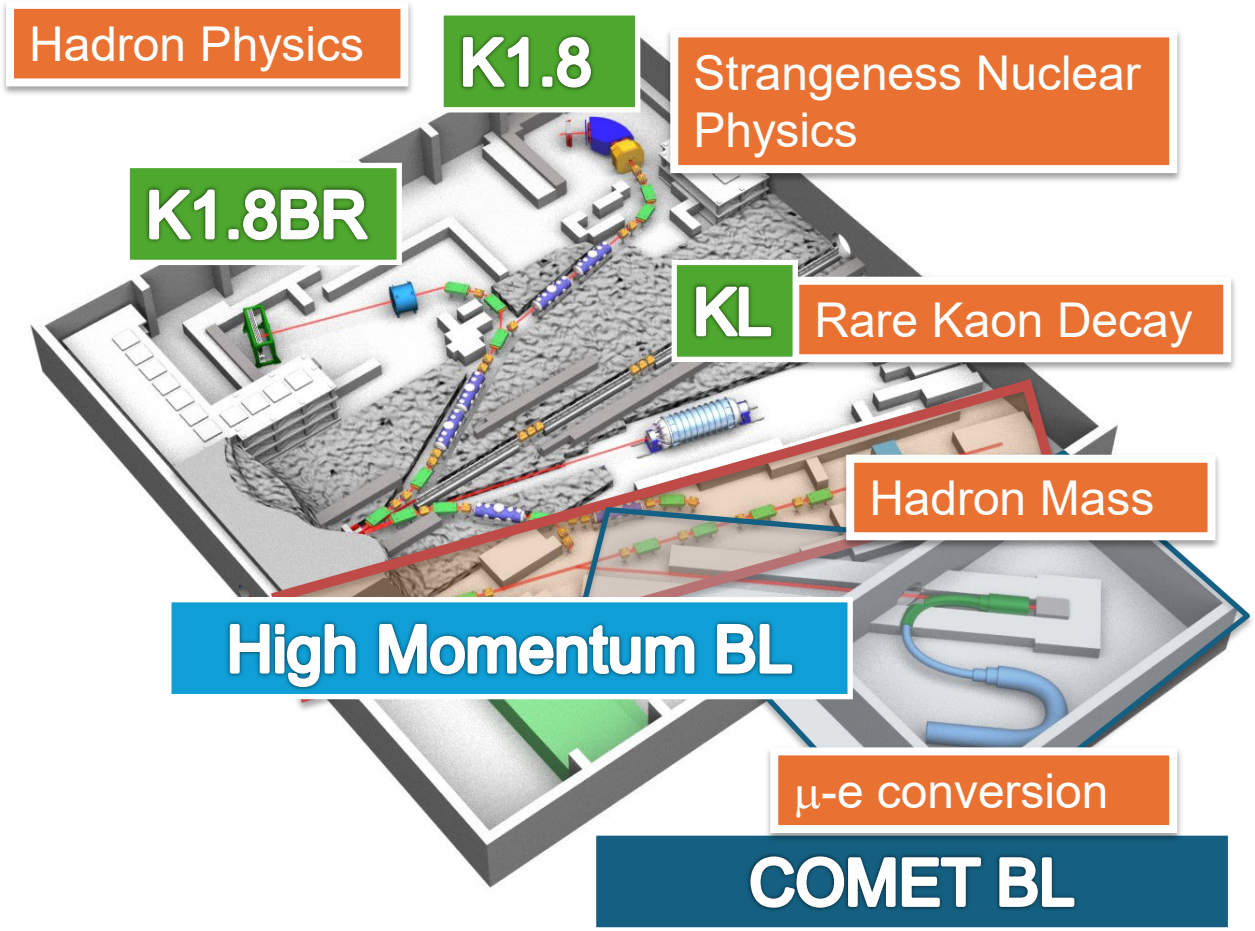






Nuclear and Hadron Physics: J-PARC hadron hall

A variety of nuclear and particle physics experiments are carried out at the hadron experimental facility.



International Collaboration Experiments

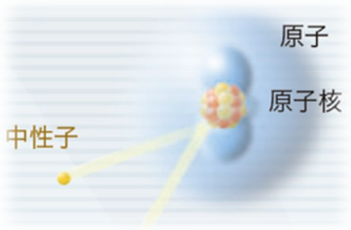
KOTO
Search for CPV in KL->$\pi^0\nu\bar{\nu}$
(Physics Run)

COMET
Search for Lepton Flavor Violation
(Construction phase)

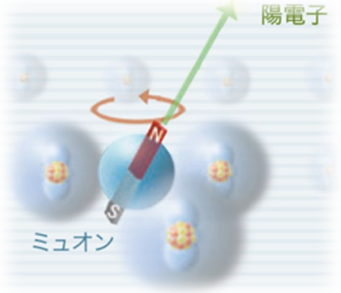
Muon g-2/EDM
Measurement of magnetic moment anomaly
(Construction phase)

Material and Life Science: J-PARC MLF

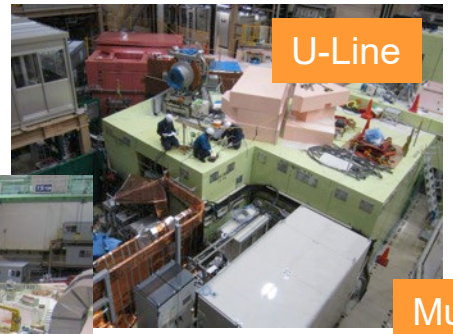
Materials and Life science using world top – class pulse neutron and muon beams

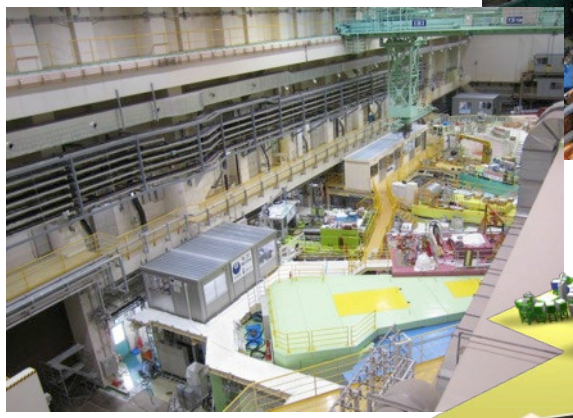


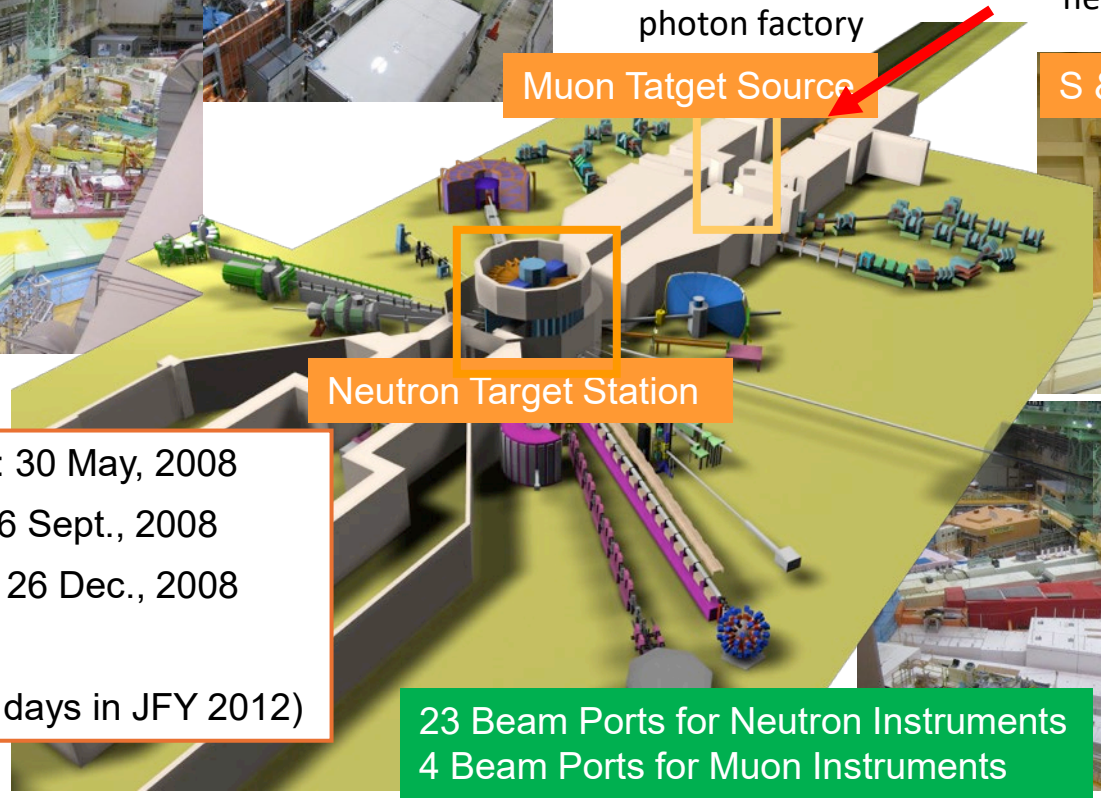
Neutron
Sensitive to light elements,
Complementary to photon factory

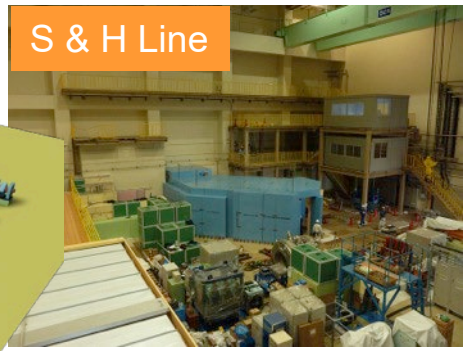


Muon
Sensitive to magnetic field in matter





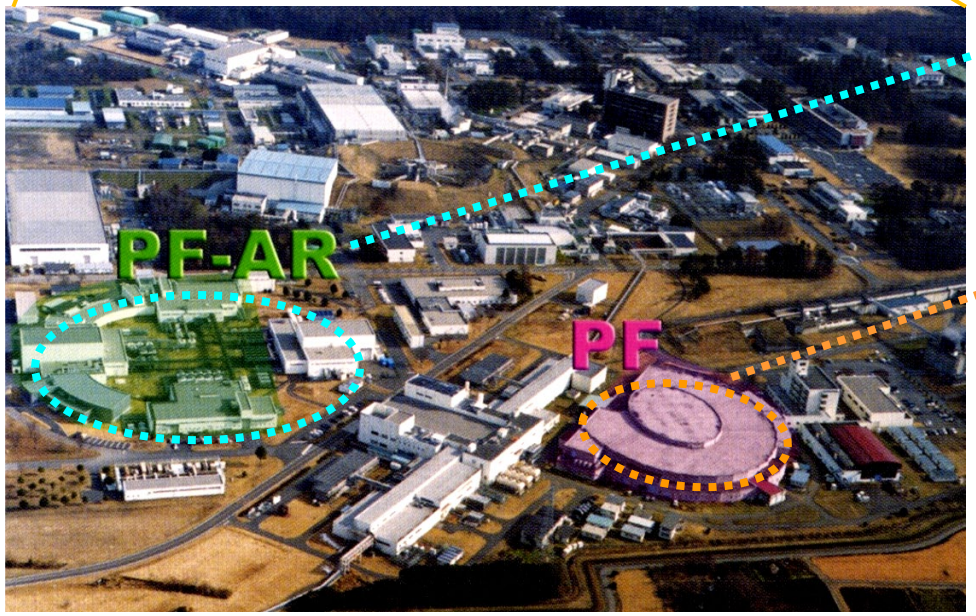




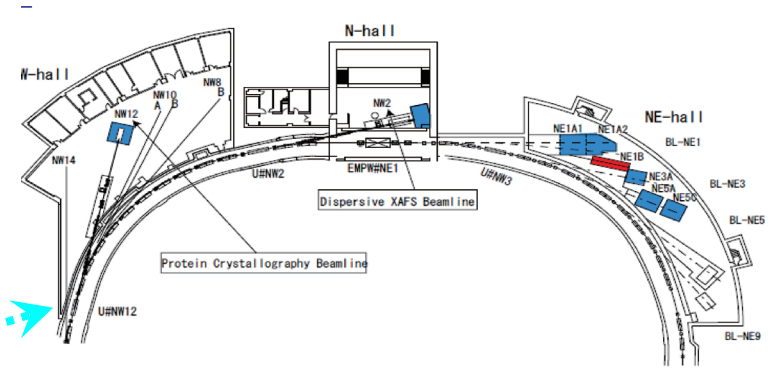
- First Neutron Beam: 30 May, 2008
- First Muon Beam: 26 Sept., 2008
- First User Program: 26 Dec., 2008
- Running at 500kW
- ~200 day/year (176 days in JFY 2012)

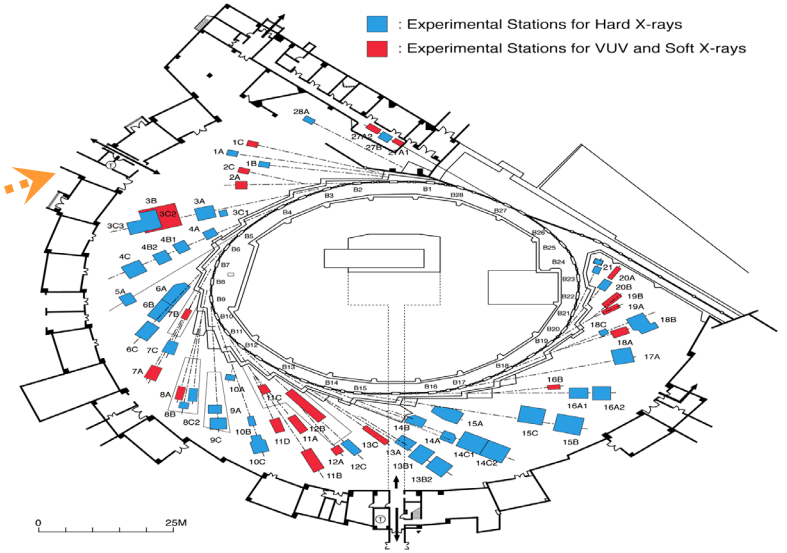
23 Beam Ports for Neutron Instruments
4 Beam Ports for Muon Instruments

Light source facilities



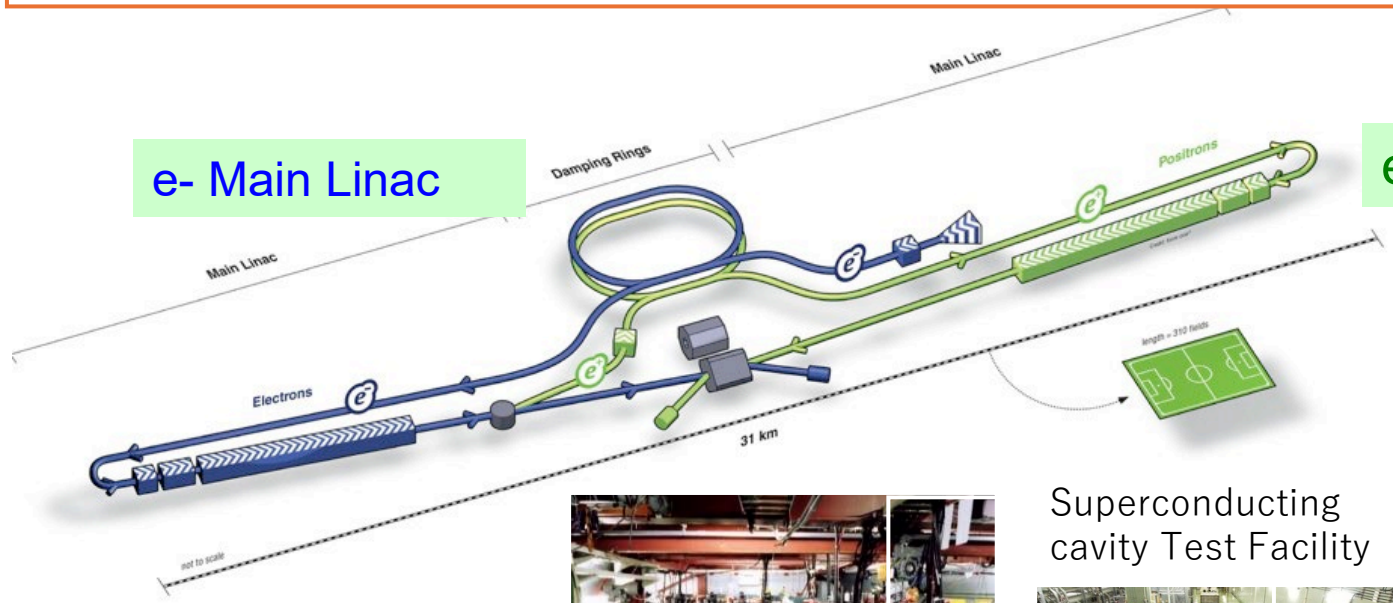
PF : 2.5 GeV, 450mA e⁻ (since 1982)
Material structure science
PF-AR : 6.5 GeV, 60mA e⁻ (since 1997)
molecular dynamics
Exp station: ~50, Users: >3000/year





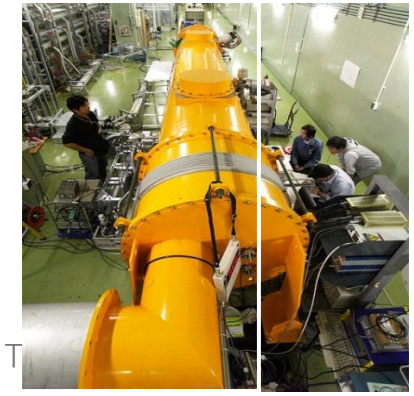
Development of International Liner Collider (ILC)

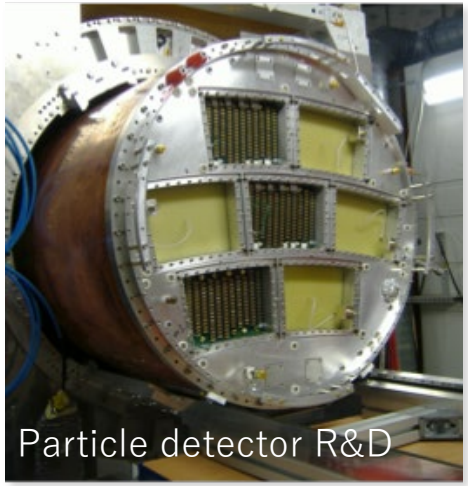
- There is a consensus among the world high energy physics community that an e^+e^- linear collider should be the next collider. The rationale is even stronger after the discovery of the Higgs particle at CERN.
- The Japanese HEP community proposed to host ILC in Japan, and this proposal was welcomed by the worldwide HEP community, ex. in Update of the European Strategy for Particle Physics, May 2013.
- MEXT, Japanese Government is investigating issues to judge hosting the ILC in Japan.
- Discussions on 250GeV ILC as a Higgs Factory are ongoing in Japan and the worldwide HEP community.



Parameters	Value
C.M. Energy	500 GeV
Peak luminosity	1.8 x10^{34} cm^{-2}s^{-1}

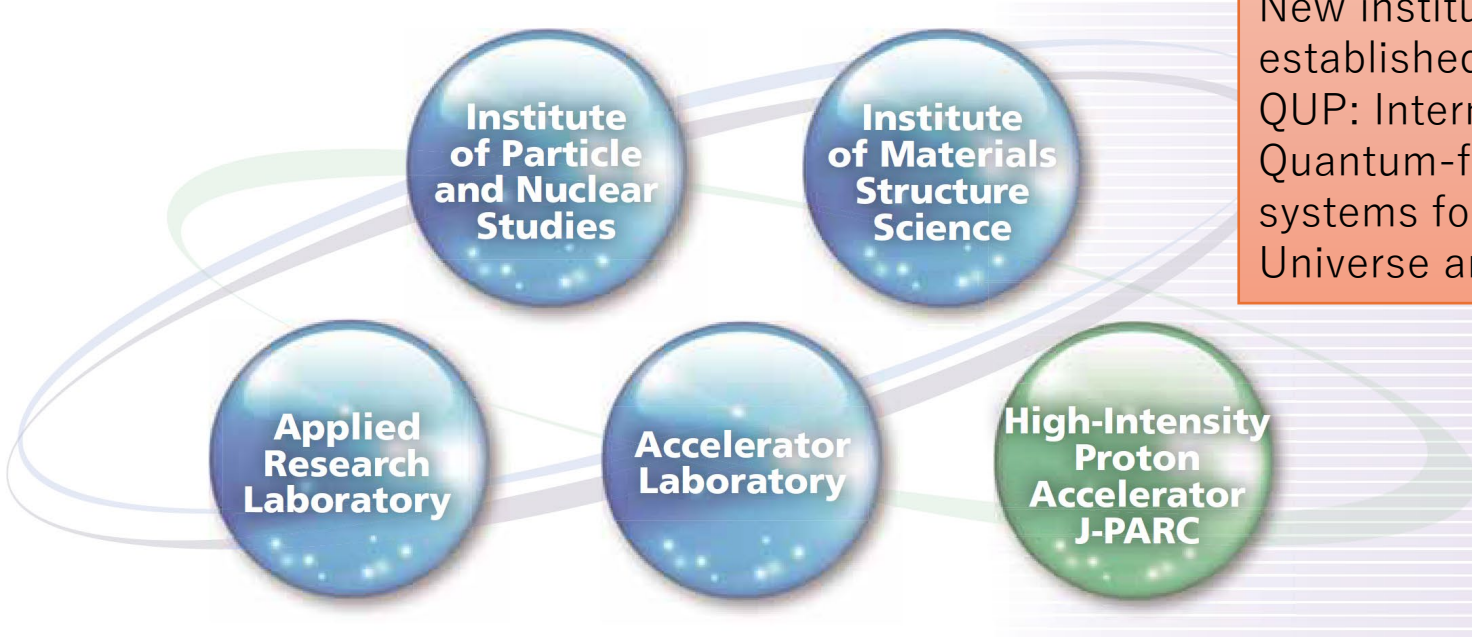
Superconducting cavity Test Facility



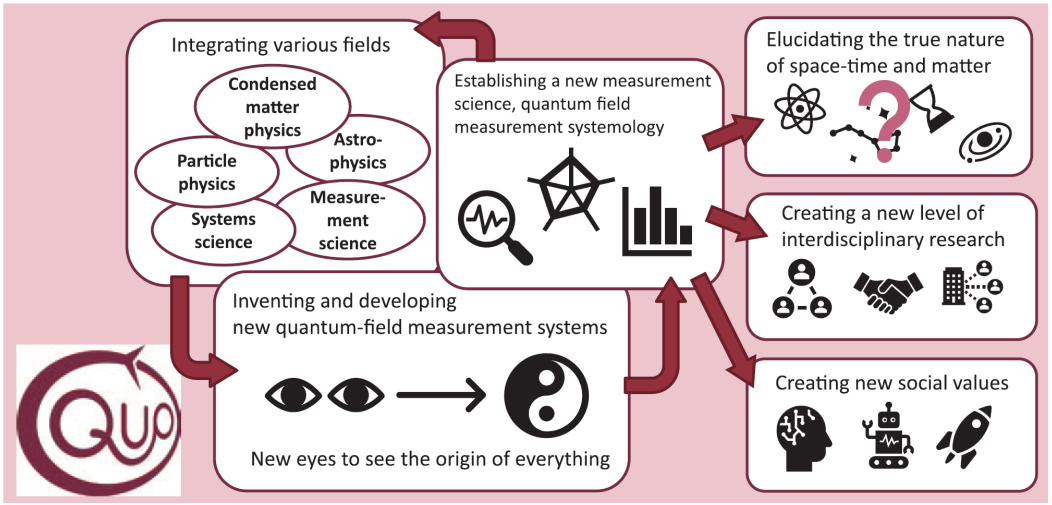


Various R&D for ILC has been conducted at KEK as an international endeavor.

High Energy Accelerator Research Organization (KEK)



New institute has been established in 2021.
QUP: International center for Quantum-field measurement systems for studies of the Universe and Particles



Applied Research Laboratory (ARL)

The Applied Research Laboratory (ARL) conducts research and development of fundamental technologies in accelerator science, including radiation science and safety, environmental and chemical safety, **computer and information network systems**, superconductivity and cryogenic technology, and precision mechanical engineering.

These technologies are necessary for the operation and advancement of research projects and collaborative research using the Large Accelerator Facility. ARL develops, applies, and provides technical support as a research institute dedicated to these goals.

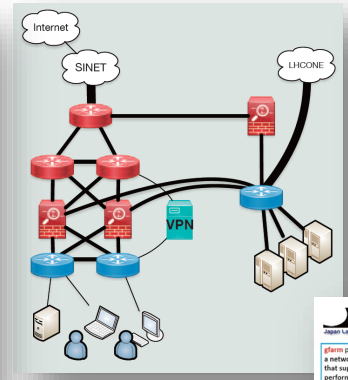
To accomplish these goals, ARL has four centers: the Radiation Science Center (RSC), the **Computing Research Center (CRC)**, the Cryogenics Science Center (CSC), and the Mechanical Engineering Center (MEC).ARL maintains and develops its technological and R&D capabilities to meet the constant demand for new knowledge, new methods, and new technological innovations required by future plans and new research projects, while establishing itself as a center for fundamental research and technological development in accelerator science.

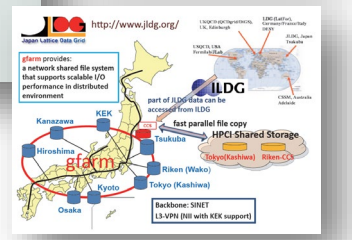
Computing Research Center (CRC)

The computing research center provides technical support in information and computing technology for various projects promoted by KEK. The activities contribute to all experiments utilizing high-energy accelerators by the research and development of IT systems. We deploy **worldwide distributed computing systems** and develop **large-scale simulation software** in collaboration with international research institutes. As computational science and technology experts, we try to make efforts in **educational activities** and **human resource development**, fostering collaboration and contributing to societal development.

CRC: focusing on scientific computing
Administration bureau: rule-making, negotiation with ministry

- Member of CRC
  - Faculty: 13
  - Engineer: 8
  - Senior fellow: 3
  - Technical and Office staff: 3
  - Support staff from companies: 1-4 for each system
- Sub-groups
  - KEK Central Computing System (KEKCC)
  - Distributed computing (Grid and Cloud)
  - Identity federation (Certificate authority, Open research data)
  - Networks (KEK-LAN, J-PARC LAN)
  - Basic IT Infrastructure（email, Web services, VPN）
  - Information security（FW, CSRIT）
  - User support desk（account management, help desk）
  - Facility maintenance（UPS, AC）
  - JLDG (data sharing for the lattice QCD simulation)
  - Supercomputer（terminated at the end of JFY2023）





CRC members

Applied Research Laboratory
Director: Y. Namito

- **Radiation Sience Center**
- **Cryogenics Sience Center**
- **Mechanical Engineering Center**
- **Computing Research Center**
  Head: Prof. T. Nakamura

KEKCC
Prof. K. Murakami (Leader)
Lect. S. Okada
Eng. S. Koike

Distributed Computing
Assoc. Prof. G. Iwai (Leader)
Assoc. Prof T. Kishimoto
Prof. T. Nakamura

AAI, ID Federation
Assoc. Prof. T. Kishimoto (Leader)
Eng. K. Omori
Eng. K. Hashimoto
Prof. T. Nakamura

Basci IT infrastructure
Prof. T. Sasaki (Leader)
Lect. A. Shibata
Eng. K. Hashimoto
Eng. K. Omori
Eng. S. Yashiro

J-PARC Network
Assos. J. Suzuki (Leader)
Eng. O. Sasaguchi

KEK Network
Assoc. Prof. S. Suzuki (Leader)
Eng. M. Nishiguchi
Eng. O. Sasaguchi

Security
Lect. R. Yonamine (Leader)
Eng. T. Nakamura
Eng. J. Ueta
Prof. S. Aoyama (SO)

User Support, Facilities
Lect. H. Matsunaga (Leader)
Eng. H. Maeda

JLDG
Lect. H. Matsufuru (Leader)

Central Computing System (KEKCC)

2024	2025	2026	2027	2028

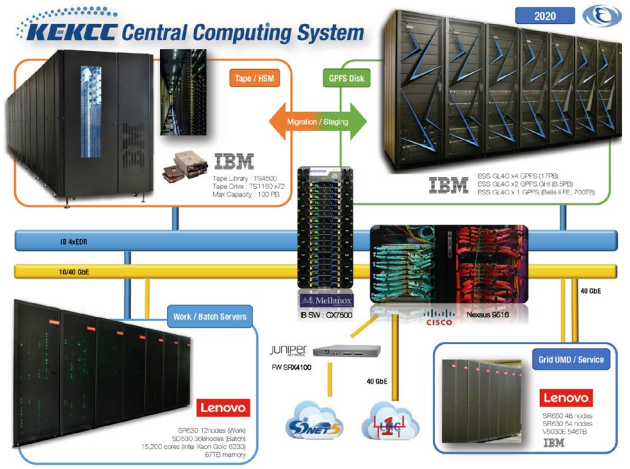
KEKCC2020 — KEKCC2024 — KEKCC2028

Construction, Data migration, Stabilization

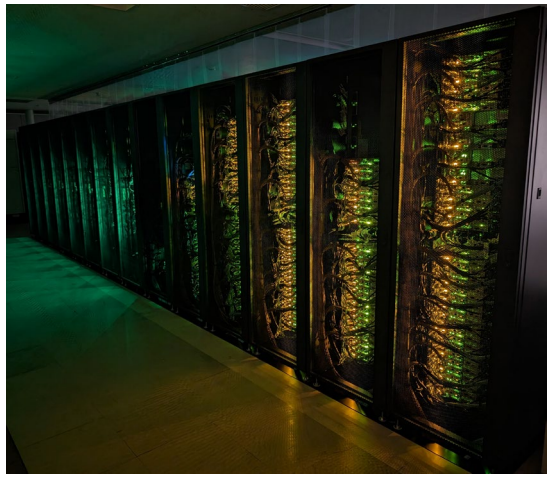
Specification, Procurement, Construction, Migration

- System Specification
  - KEKCC2020
    - CPU: 15,200 cores
    - Disk: 17 PB + 8.5 PB (HSM)
    - Tape: 100 PB（capacity）, 72 drives
  - KEKCC2024
    - CPU: 12,096 cores
      performance improvement: 170%/core, 140% in total
    - Disk: 20 PB + 10 PB (HSM)
    - Tape: 120 PB (capacity）, 70 drives
- Status
  - Lack of resources: procured resources are insufficient for demand from experiments
  - Filled up all job slots regularly
  - 46PB of data is already archived in the tape library
- Research and Development
  - It is essential to constantly investigate available technologies for system renewal in every four years.
  - The state of the supply chain and fluctuations in exchange rates have made it challenging to keep a stable quantity of resources can be procured at a fixed budget.
  - Dominance: Hyperscaler, Disadvantage: Academic institutes

Technology surveillance



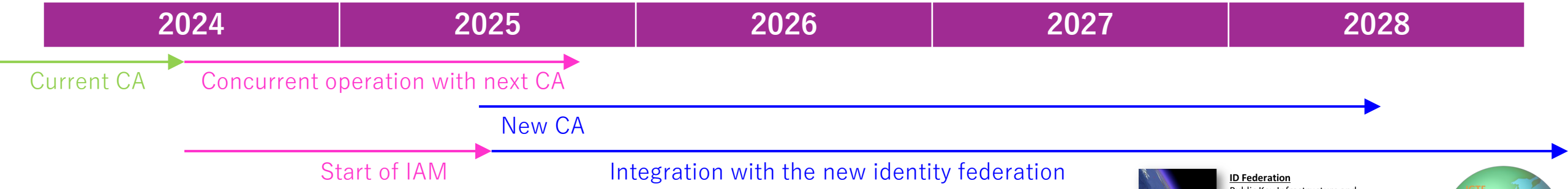
KEKCC2020



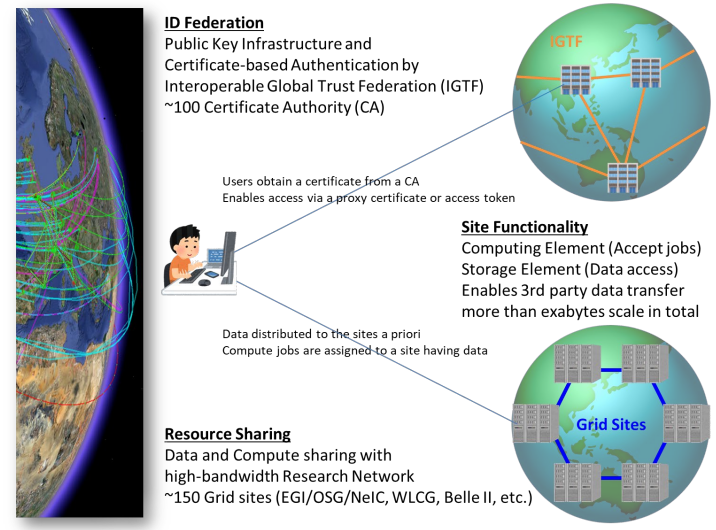
KEKCC2024

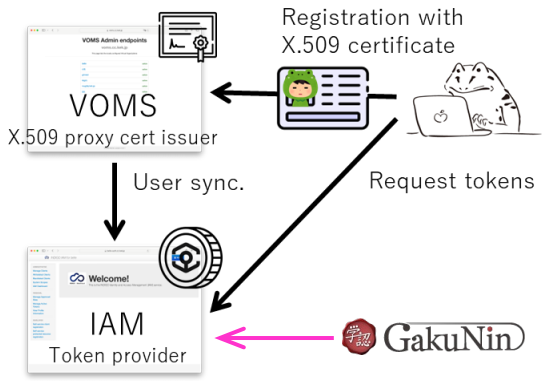
Jun. 3, 2024

Distributed Computing and Identity federation

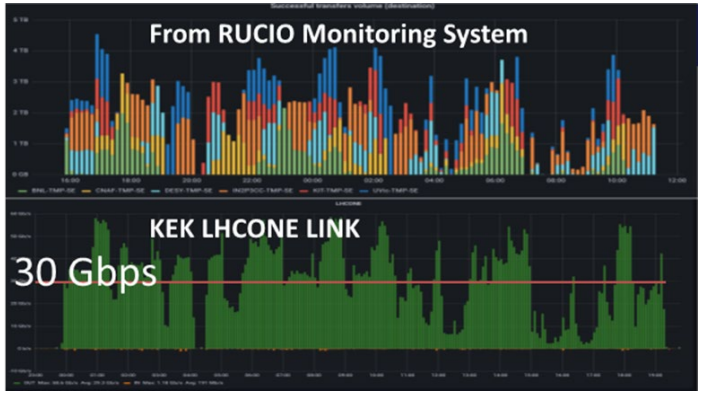


- Grid Certificate Authority (CA)
  - The KEK CA has been an IGTF accredited CA authority and has issued approximately 8,000 Grid certificates for various Japanese institutes and experiments since 2006. Supporting project: Belle II, ATLAS, ILC, J-PARC muon g-2/EDM, T2K, KAGRA, JLDG, **Hyper-K**, **KOTO**, etc.
  - The current CA will reach 20 years of operation by the end of November 2025. The issuance of new certificates will be discontinued, and the CA will be replaced with the new system.
- Grid Service
  - KEK Grid site is one of the certified sites of the European Grid Initiative (EGI).
  - **KEK became an observer of the Worldwide LHC Computing Grid (WLCG) in 2015**.
  - KEK provides some central services as a Tier-0 site of Belle II, in addition to services in the usual Grid sites.
- Research and Development
  - Transition to the new identity federation replacing Grid certificate authentication
  - Enabling resource access using IAM tokens instead of VOMS proxy certificates



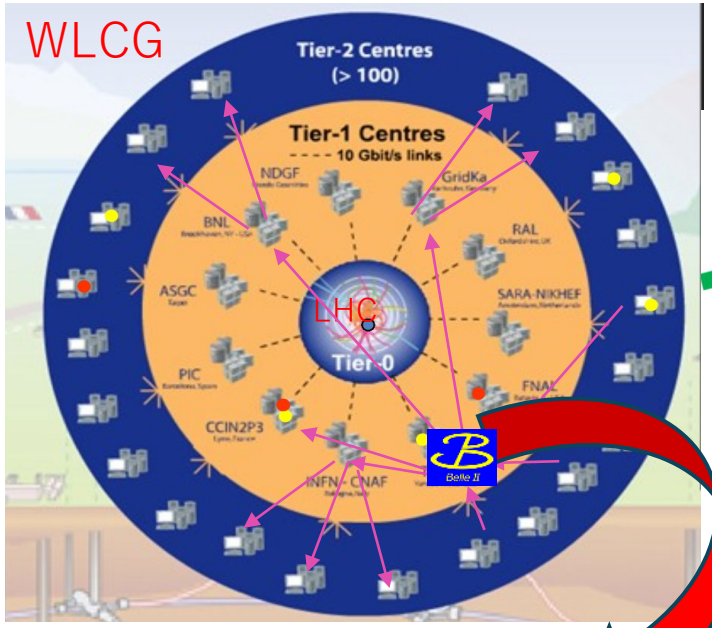


VOMS proxy → IAM token

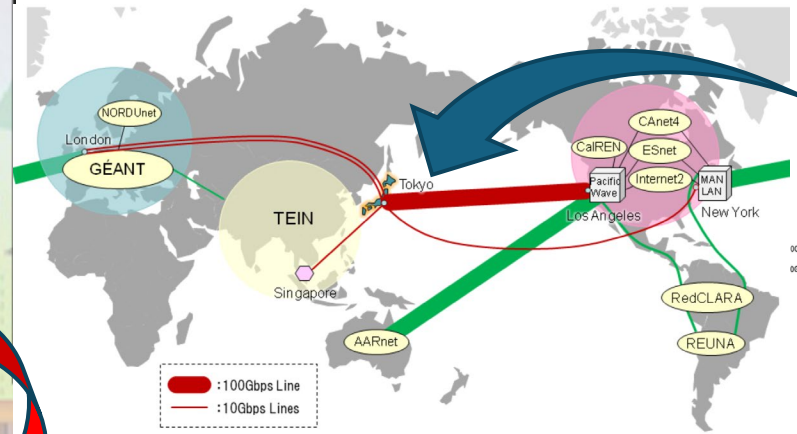


WLCG Data Challenge 24

Overview of the Grid data flow

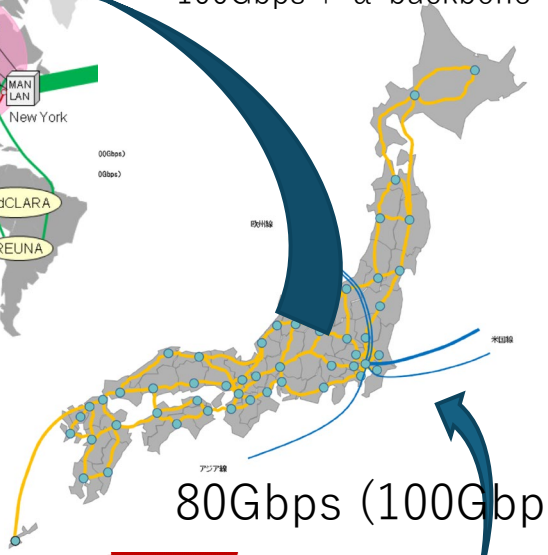


Belle II Grid over WLCG(KEK and Belle II)



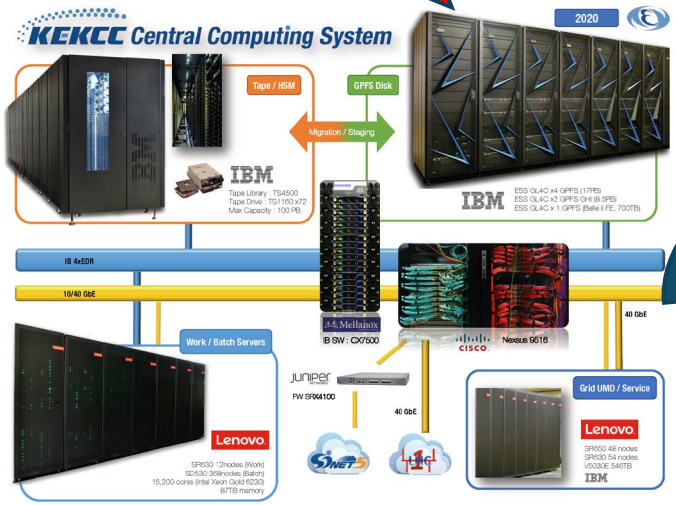
SINET6

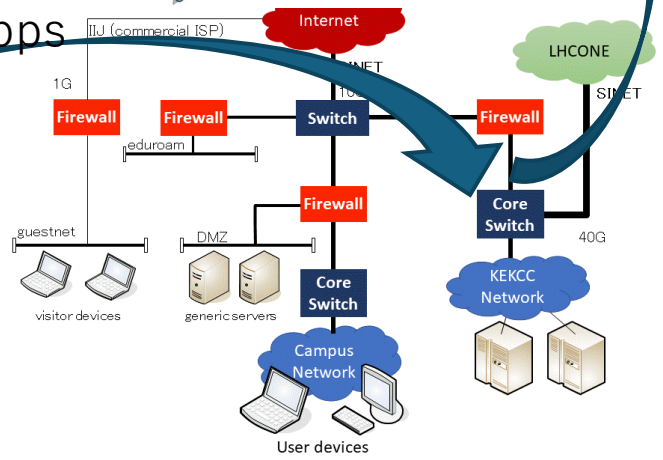
100Gbps + α backbone



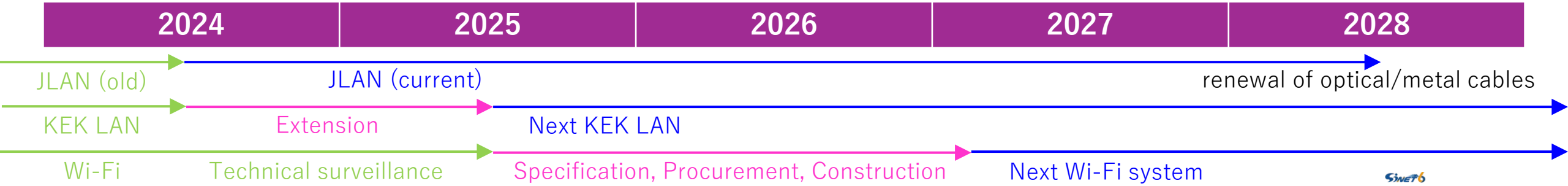
80Gbps (100Gbps)

100Gbps

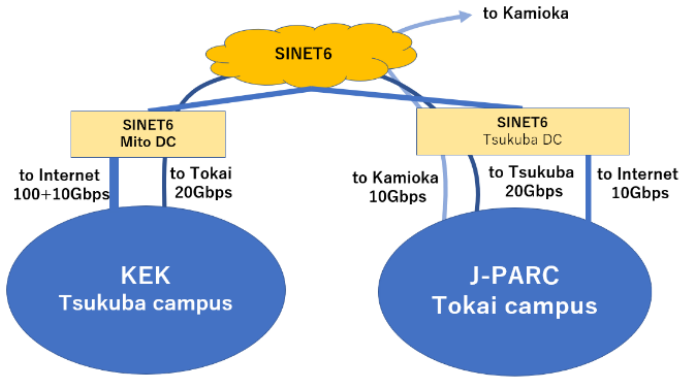


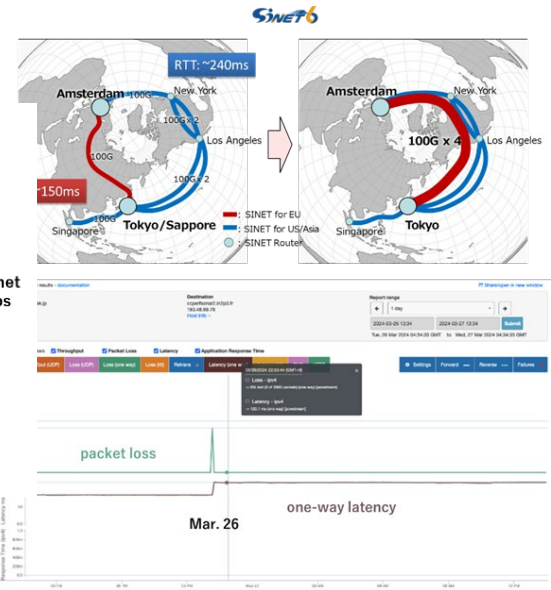


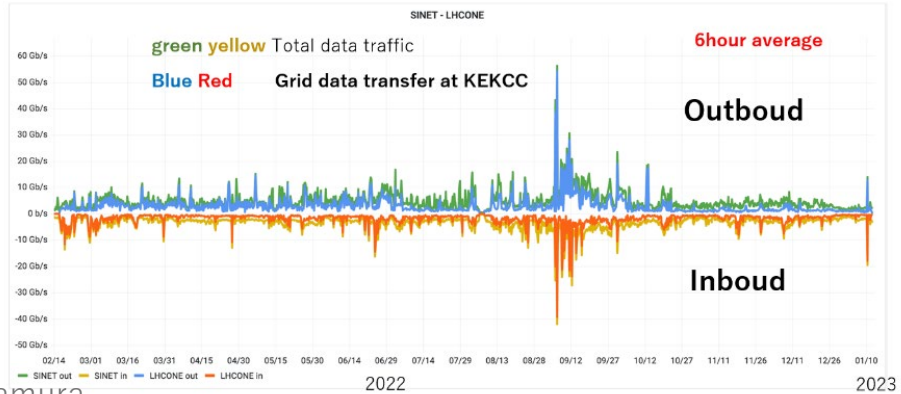
Networks, KEK-LAN and J-PARC LAN



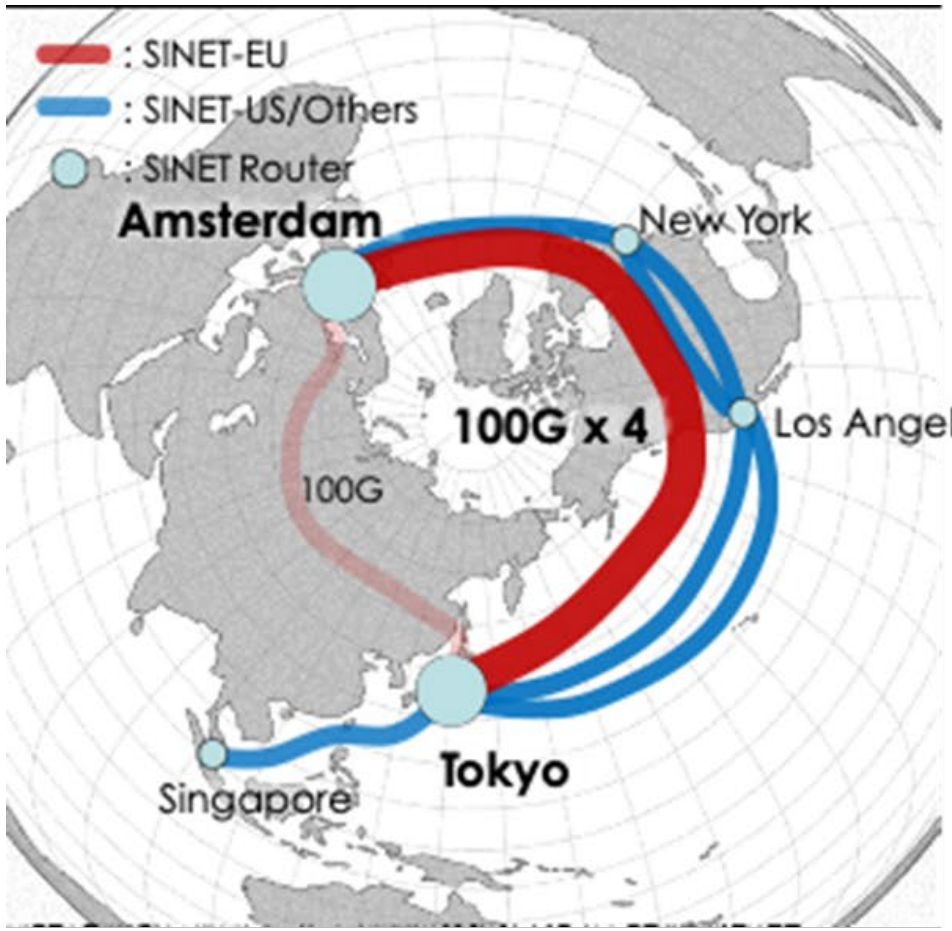
- KEK-LAN
  - Approximately 7,300 devices connected at the Tsukuba Campus
  - External connection to SINET (Japanese NREN) is 100+10 Gbps
  - **KEK became the first site other than the LHC experiments to connect to the LHC Open Network Environment (LHCONE) since 2016.**
  - The lease will be extended for one year from the summer of 2024, and the system renewal to the next system will be carried out in August 2025.
  - The wireless LAN system was excluded from the KEK LAN procurement due to the rise in equipment prices, so it is necessary to consider their procurement.
- J-PARC LAN
  - Approximately 5,800 devices are connected within the Tokai Campus
  - The Tsukuba-Tokai Campus connection is provided at a bandwidth of 20 Gbps via SINET L2VPN.
  - **The Tokai-Kamioka connection is provided at a bandwidth of 10 Gbps to provide T2K timing information.**
  - The system was successfully migrated to the new system in summer 2024.





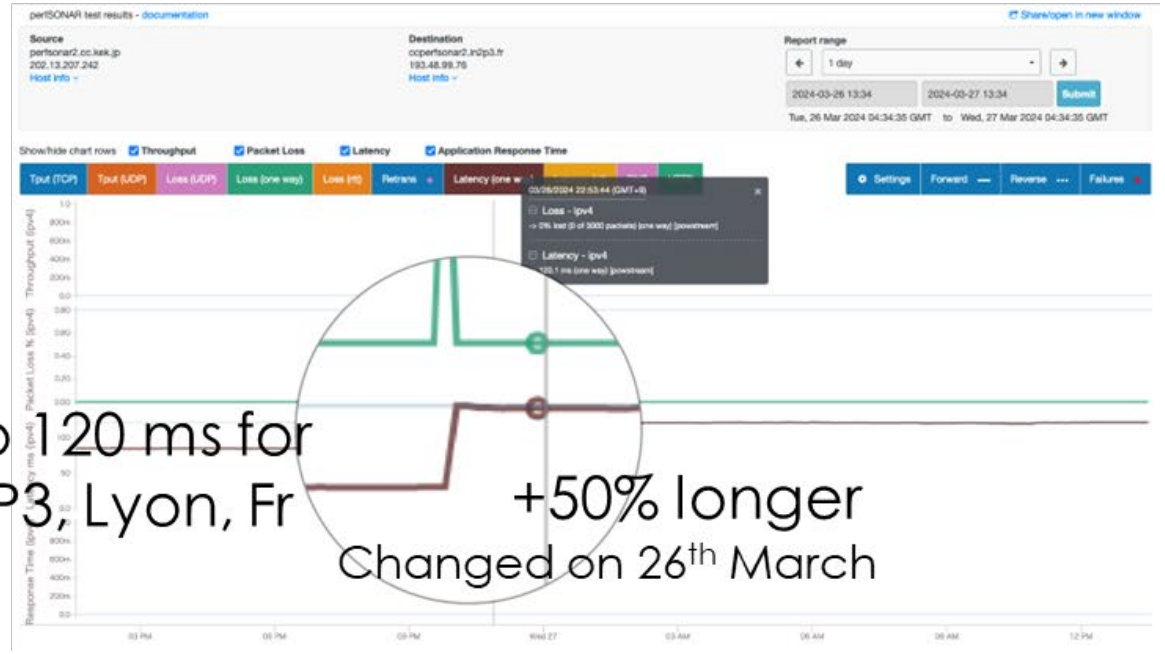


International network connectivity

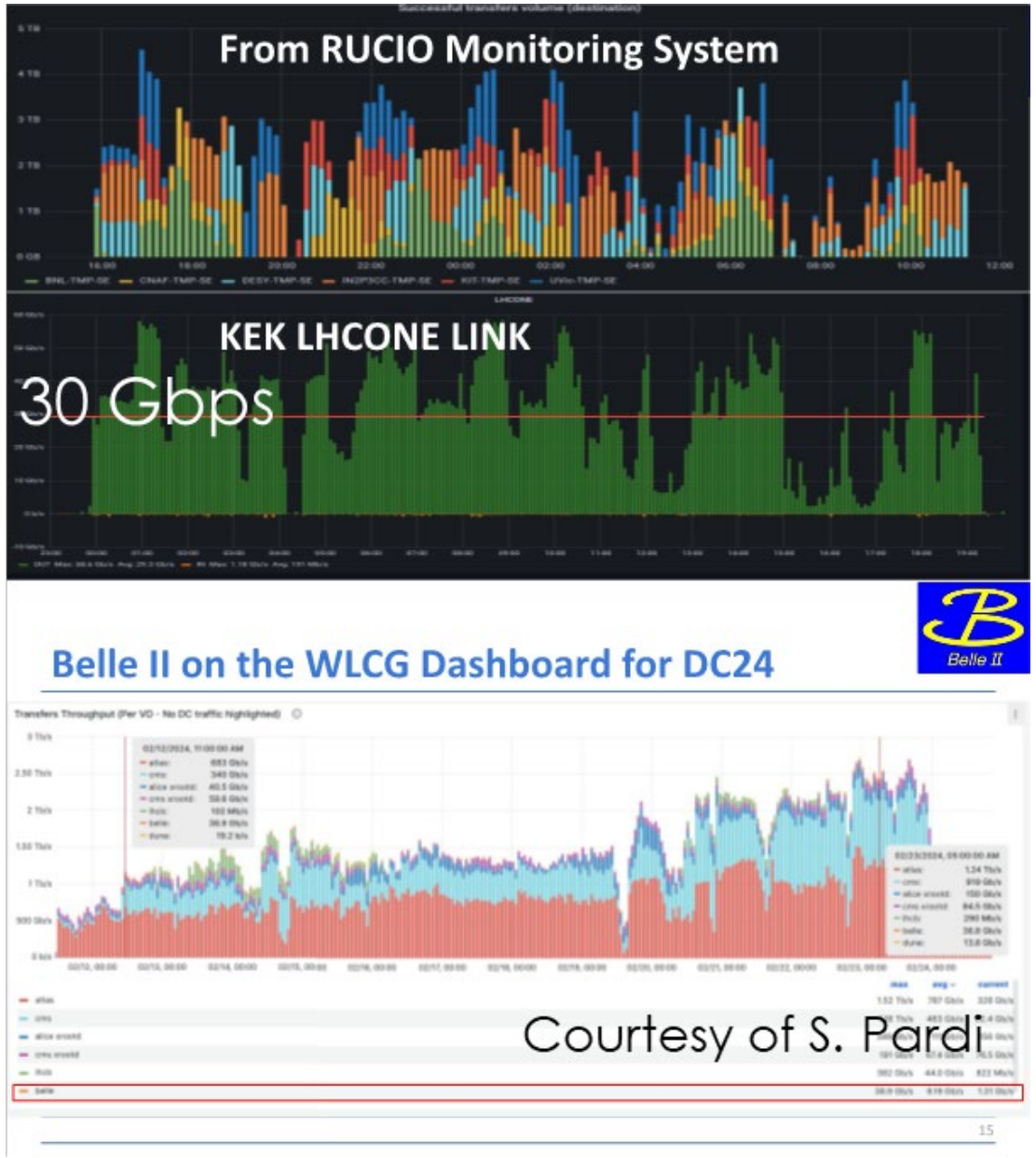


Siberian 100G route between Japan and Euro has been upgraded to the transatlantic route with 100G x4 lines
Dedicated line for the traffic between Japan and Euro, not shared with traffic for the US
To minimise the latency:

- traffic passes through fewer routers on the shortest route close to the Arctic



WLCG data challenge 24



WLCG Data Challenge aims to demonstrate readiness for expected HL-LHC data rates, coordinated by WLCG

Belle II DC24: Raw data replication from KEK to Belle II RAW data centres:

BNL, UVic, CNAF, DESY, KIT, and CC-IN2P3

260 TB / 50K files of pseudo-RAW data have been transferred in 20 hours at an average of 30 Gbps from KEK to RDCs

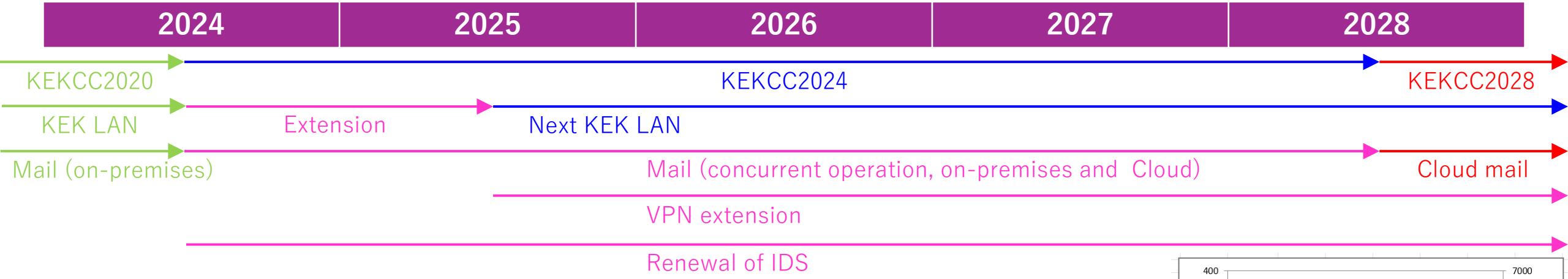
Belle II HL scenario: 40 TB /day (3.7 Gbps)

Transfer protocol: Only HTTPS protocol in use, no GridFTP any more

This is a mandated step for migrating to OIDC

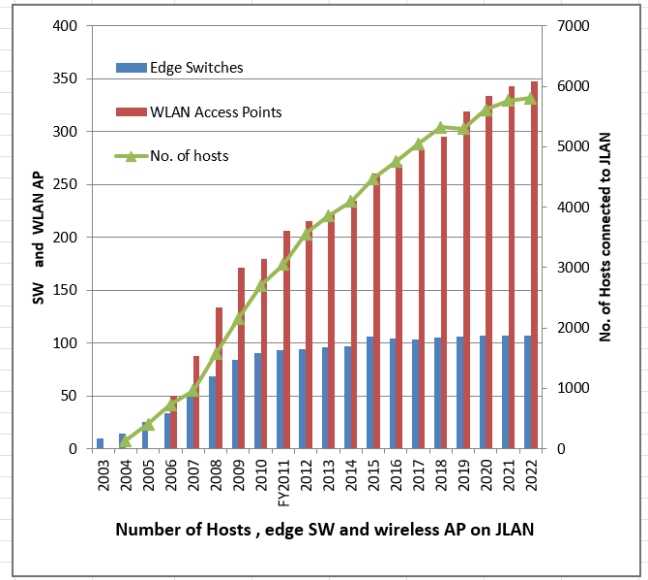
Most of network traffic load among RDCs is via IPv6

Basic IT Infrastructure and Security



- Basic IT Infrastructure
  - **Moving to a cloud-based email system**
    - Migrate to cloud services by the end of the current KEKCC operational period (Aug. 2028).
  - Web services (updated with KEKCC renewal)
    - KDS, Conference web/Indico
    - KEK wiki
    - KEK cloud (online storage)
  - Wireless network for users
    - eduroam
    - Guest net
    - KEK Spot
    - VPN
  - User Support
    - Support desk
    - ccPortal (account request system)

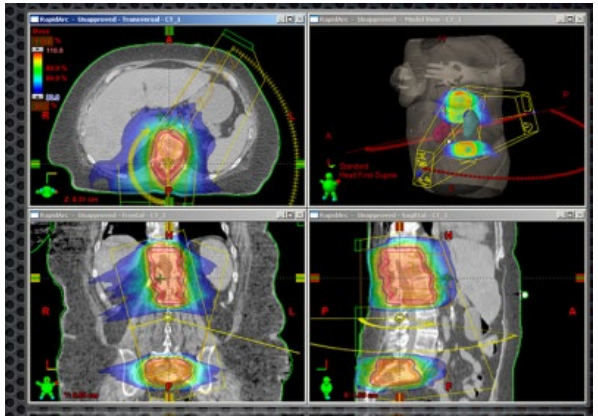
- Information Security
  - KEK CSIRT
  - Monitoring by JSOC and NII SOC
  - Security equipment operation
  - Technical support for end users
  - Security training

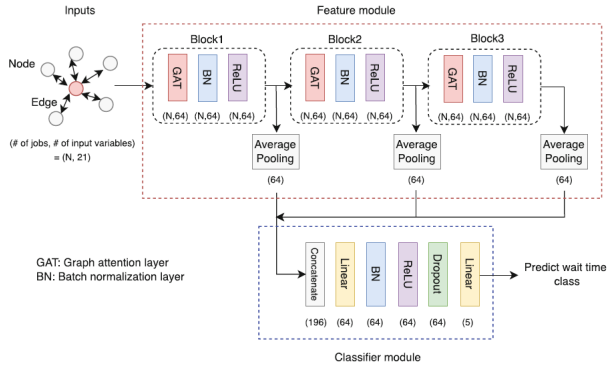


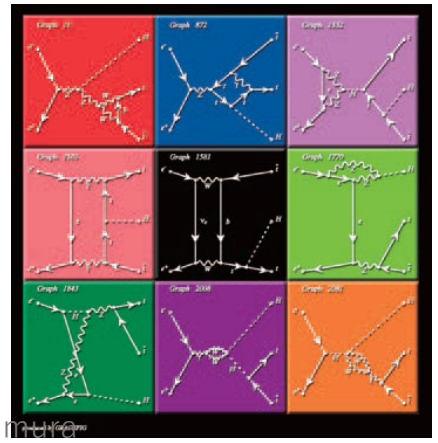
- Information system section in J-PARC
  - Operation of J-PARC LAN
  - Maintenance and operation of J-PARC mail, Web, VPN
  - Information security of J-PARC

R&D, International collaboration, Education

- **Geant4: toolkit for the simulation of the passage of particles through matter**
  - Development and Maintenance of core software
  - Development of medical application
- GRACE: a system for perturbative, automatic numerical calculation of cross-sections of particle collision reactions on a computer
- Lattice QCD and Data sharing (JLDG)
- Simple deployment method of Grid middleware
- Optimization of large-scale computer systems by Deep Learning
- Exa-scale storage working group
  - Review and study of high-density, high-capacity tape technology. A key technology for data analysis in high-energy experiments (cost performance, long-term data stores, Green-IT)
  - JAXA, Riken, UTokyo, Meteorological Agency, IBM, KEK, etc.
- **Particle physics computing consortium in Japan**
  - Sharing computing technology as a standard technology across experimental fields of particle, nuclear, and astrophysics
  - Fostering young leaders of the next generation and career paths through the organization of a summer school for graduate students (IINAS-NX)
  - UTokyo-ICEPP, UKobe, KEK-IPNS/CRC, etc.
- **HEPiX forum**
  - Information exchange and cooperation with foreign accelerator-related laboratories
  - ASGC, BNL, CERN, DESY, FNAL, IHEP, IN2P3, INFN, JLAB, KEK, KIT, Nikhef, PIC, RAL, SLAC, TRIUMF, etc.







Summary

- We provide extensive services and computing resource provisioning to support KEK's various projects with fewer staff members compared to IT departments at other accelerator research laboratories.
- We endeavor to evaluate the necessity of legacy services and either phase them out or modernize them.
- We are proactively making preparations to implement new technologies such as single sign-on, ID federation, streamlining of account management without human intervention, and AI-driven help desk automation.
- We believe collaboration and building connections with academic institutes worldwide are crucial for staying current with the latest technologies and contributing to their advancement.