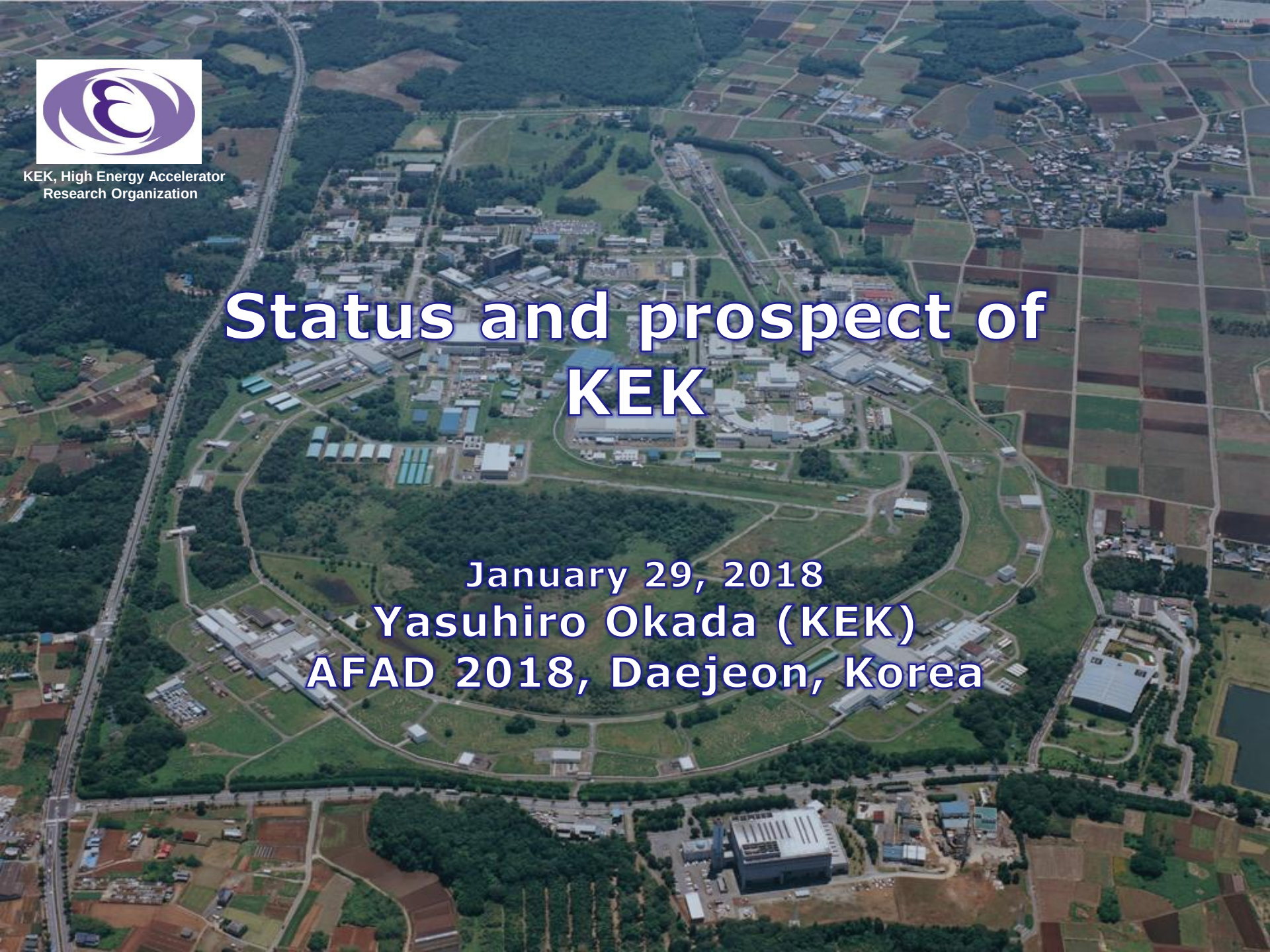


KEK, High Energy Accelerator Research Organization

Status and prospect of KEK

January 29, 2018

Yasuhiro Okada (KEK)

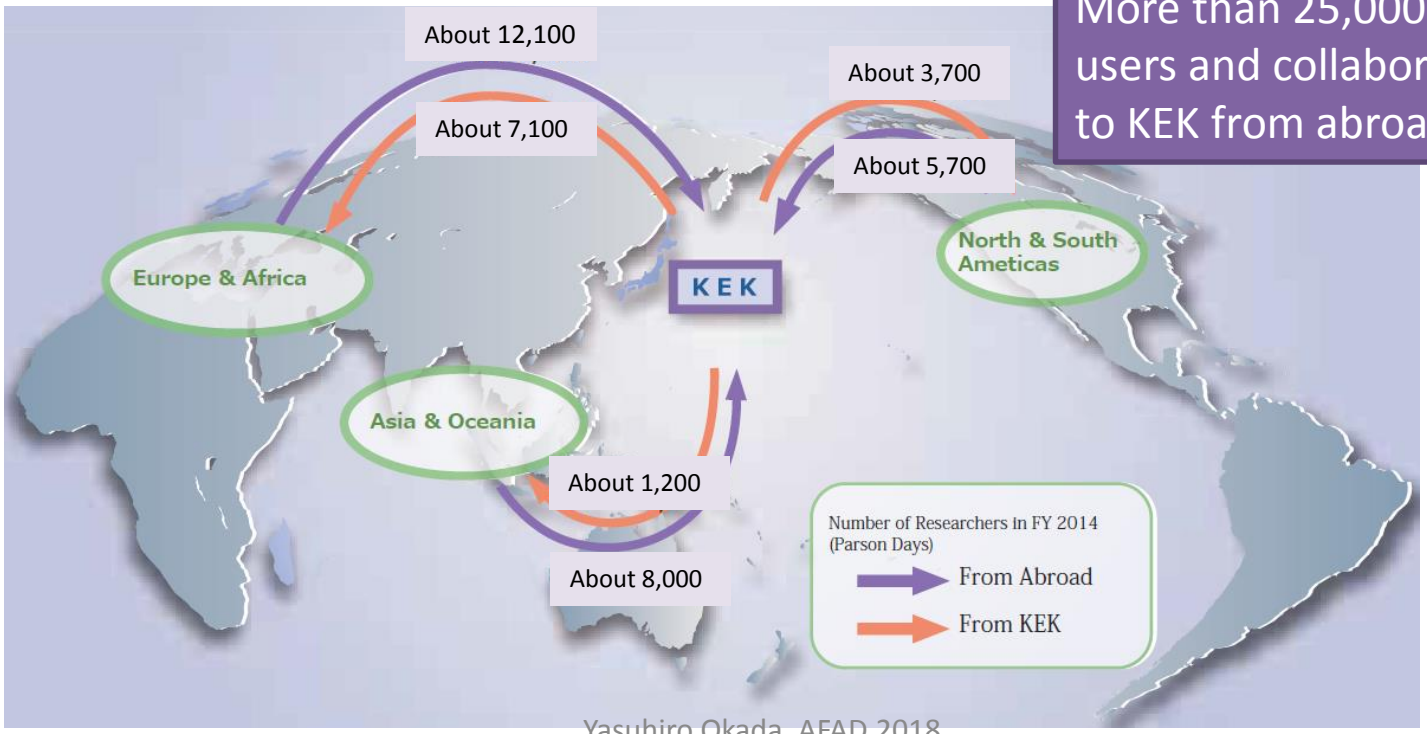
AFAD 2018, Daejeon, Korea

KEK
High Energy Accelerator Research Organization

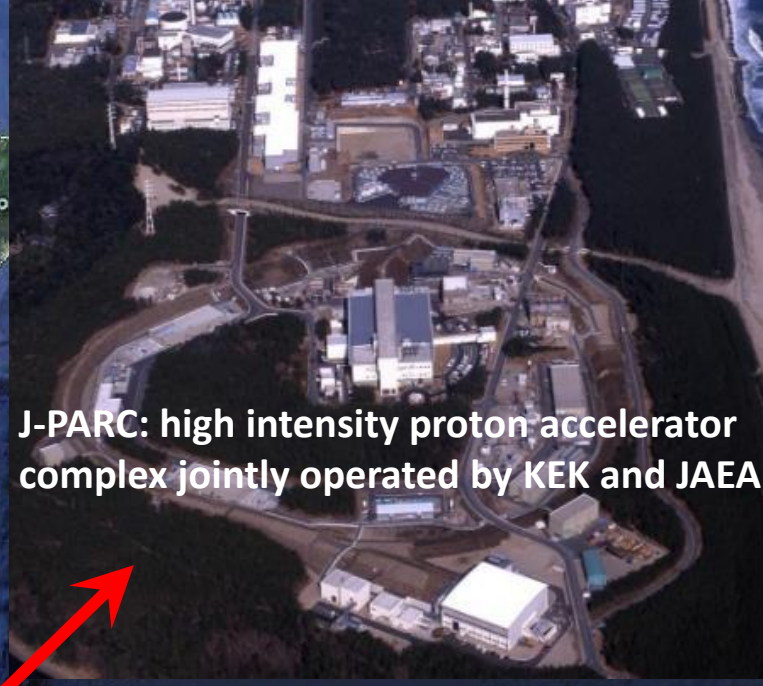
High Energy Accelerator Research Organization (KEK)

- KEK is an Inter-University Research Institute Corporation, first established in 1971 as National Laboratory for High Energy Physics.
- Now, KEK covers a wide area of scientific fields from particle and nuclear physics to materials and life sciences by constructing and operating large accelerator facilities.
- We have about 700 permanent staff, 100 students, and 8,000 users/year.
- KEK is one of leading accelerator science centers worldwide.

More than 25,000 person-days users and collaborators come to KEK from abroad per year.



Electron accelerators in Tsukuba and proton accelerators in Tokai



J-PARC: high intensity proton accelerator complex jointly operated by KEK and JAEA

KEK Tsukuba: SuperKEKB, PF, ATF

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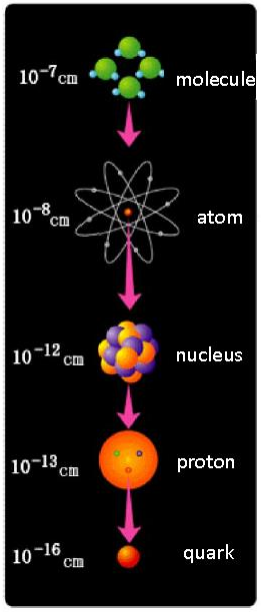
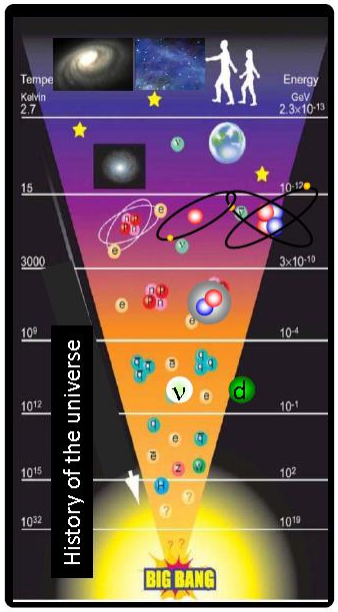
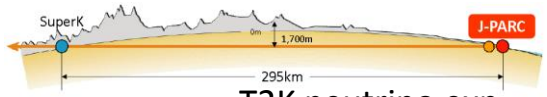
Diversity in accelerator based sciences

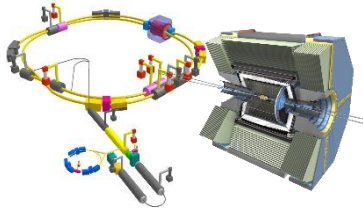
Pursuing fundamental laws of nature



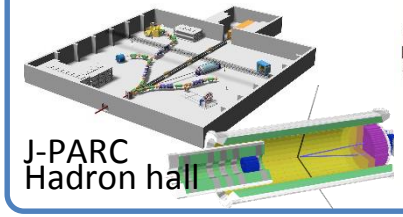




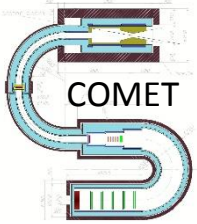
T2K neutrino exp.



SuperKEKB and Belle II



J-PARC Hadron hall



COMET

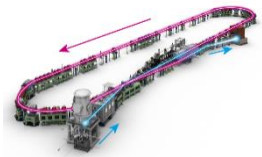
Basic science

Material science and its applications

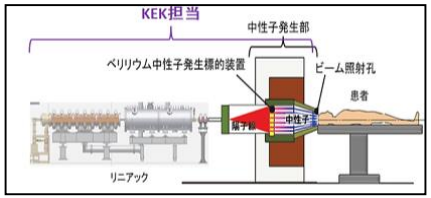
KEK

Technical development and its applications

Superconducting accelerator



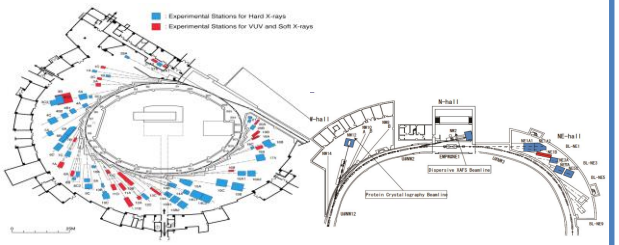
Energy recovery linac

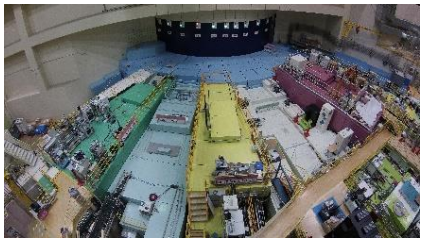


Accelerator-based BNCT

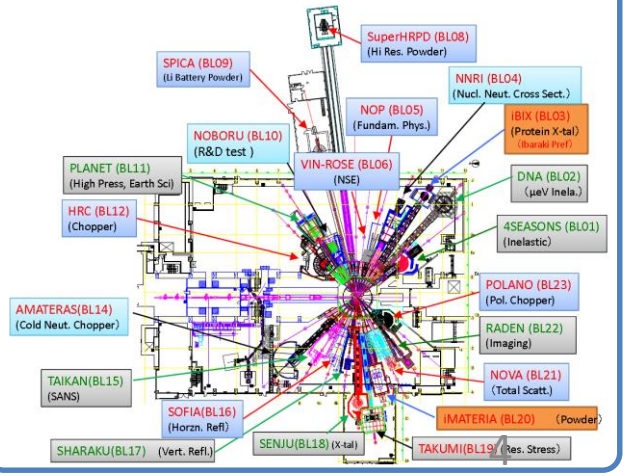
Pursuing origin of function in materials

Photon factory X-ray as a probe





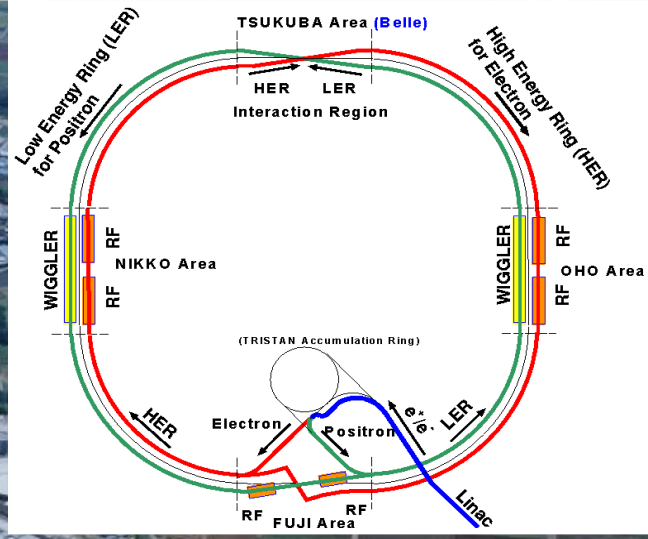
J-PARC MLF neutron and μ as a probe

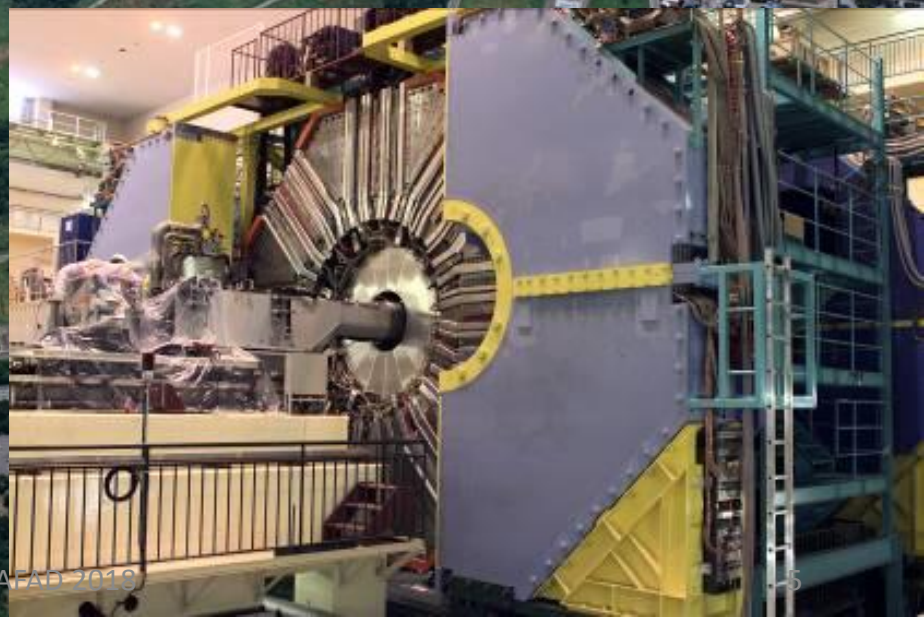


KEKB and Belle

↓

SuperKEKB and Belle II





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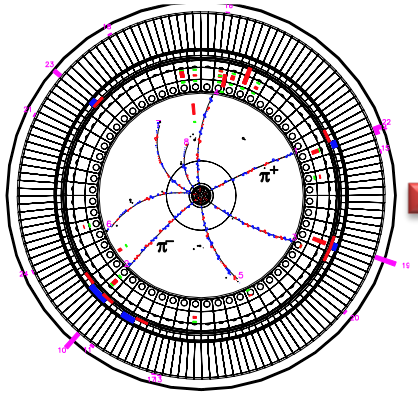
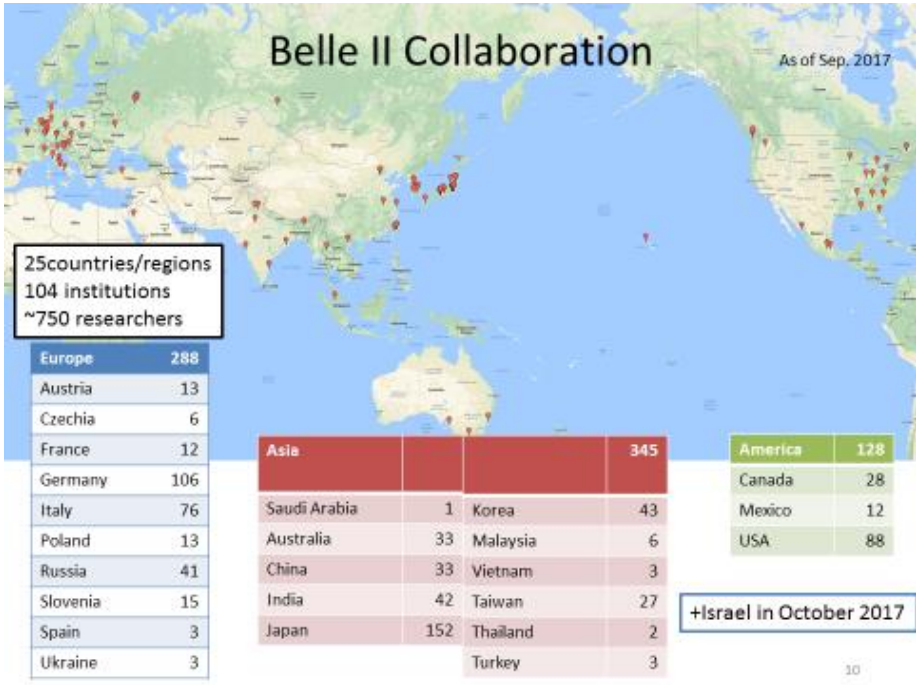
SuperKEKB and Belle II

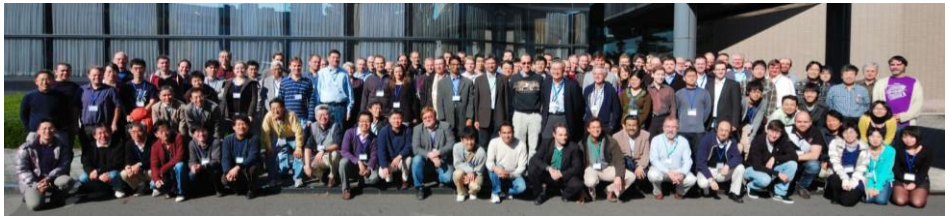
- Belle, along with BABAR/SLAC, discovered CP violation in *B* mesons, and confirmed Kobayashi-Maskawa theory.
- The apparatus is now being upgraded to search for new physics beyond this theory.
- The phase 1 accelerator commissioning was successfully completed in 2016.
- The Belle II detector was rolled in April, 2017.
- The phase 2 commissioning without the vertex detector will start soon.
- Full physics run will begin early in 2019.



2008 Nobel Physics prize

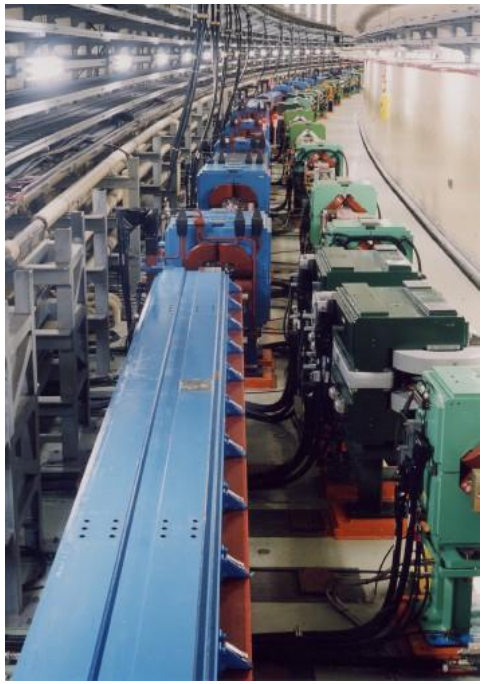
Dr.Kobayashi Dr.Maskawa

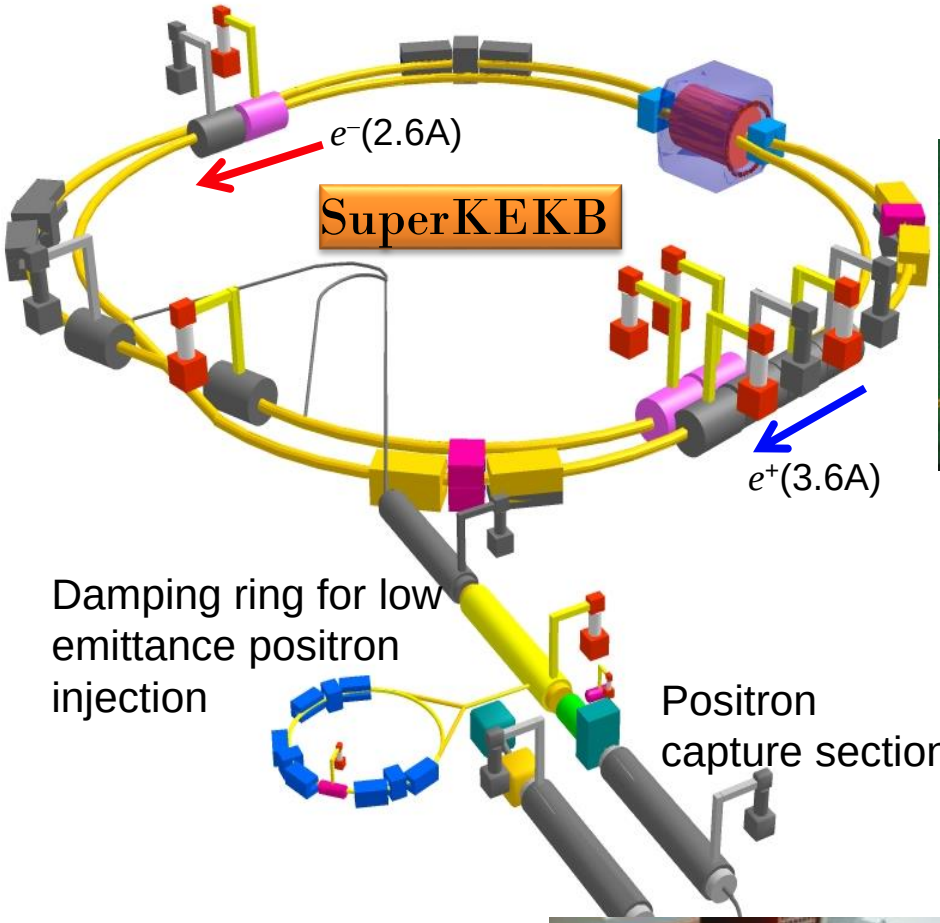




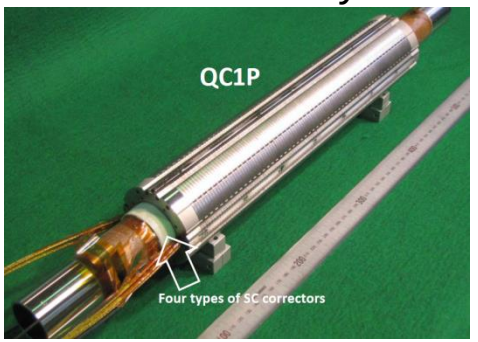
Accelerator upgrade

Low emittance lattice





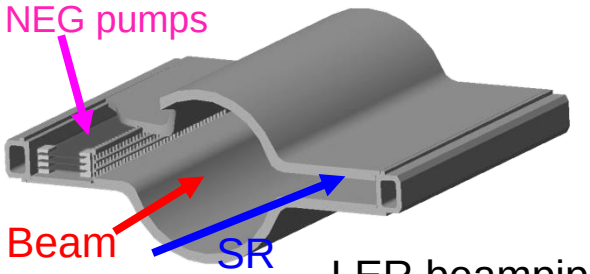
IR with β_y*=0.3mm
SC final focus system



Damping ring for low emittance positron injection

Positron capture section

Add RF systems for higher beam current



LER beampipe to suppress photoelectron instability

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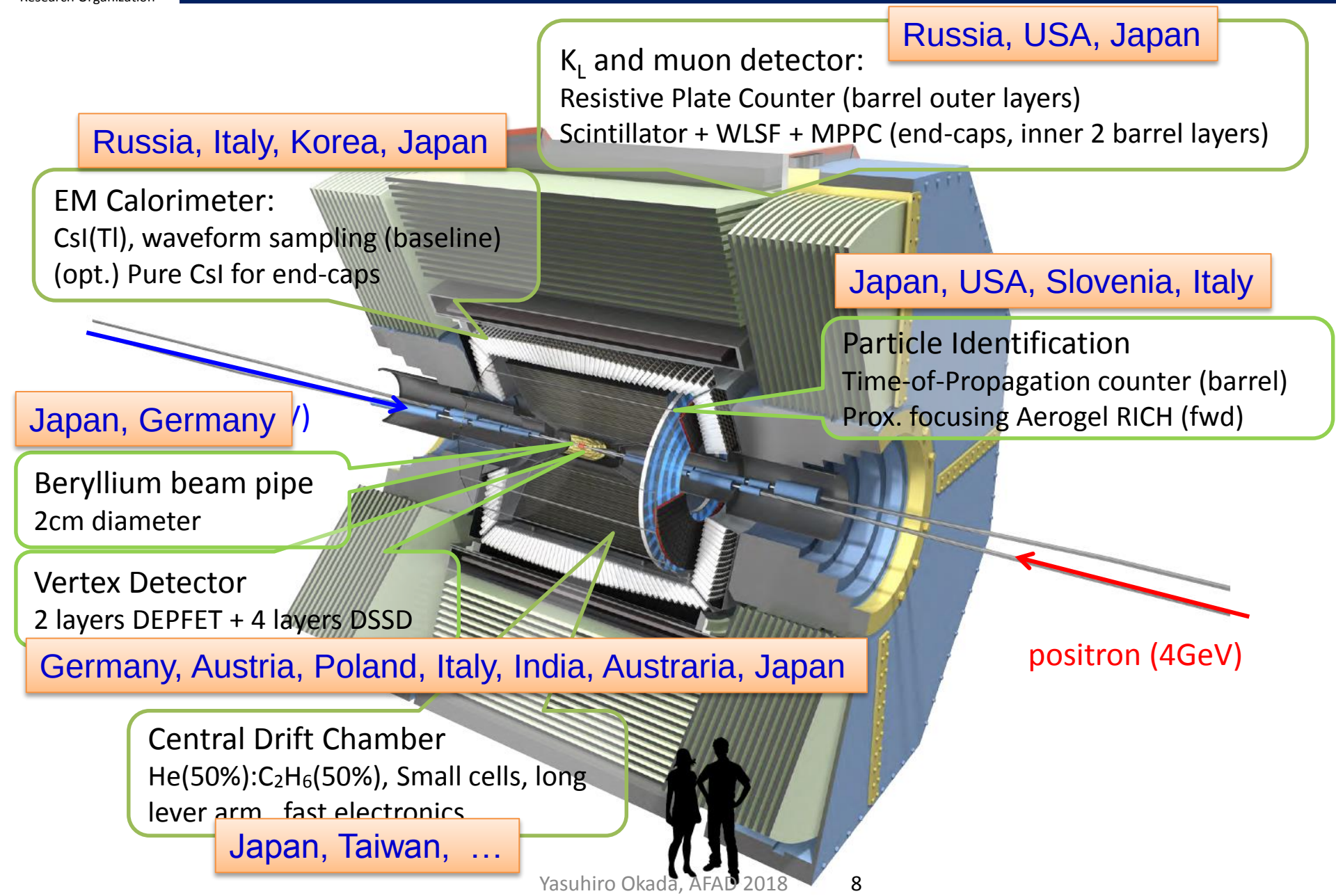
Belle II Detector



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Belle II is now at IP

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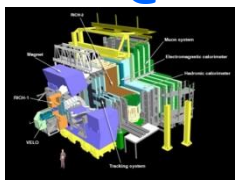
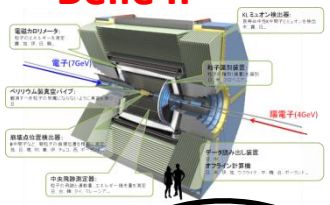
New Measurement Map

LHCb@CERN



Belle II



>>analyses LHCb is good at

>>analyses Belle II is good at

Only electrically charged particles (muons) in the final states

Bs, Λ_b

Bs →μμ

SUSY, Charged Higgs

B →K*ll

Model-indep. NP

LUV

new CPV

D^0 CPV

Model-indep. NP

A(K π)

Neutral particles (γ, ν K_S etc.) in the final state

new CPV

b →sqq

B→ K_S π^0 γ

B→h ν ν , τ ν

B→D* τν

B→D^0 τν

LUV

tau

τ→μγ

LFV

Charged Higgs

Inclusive analysis

b→ s/d γ

b→ u l ν

SUSY, charged Higgs

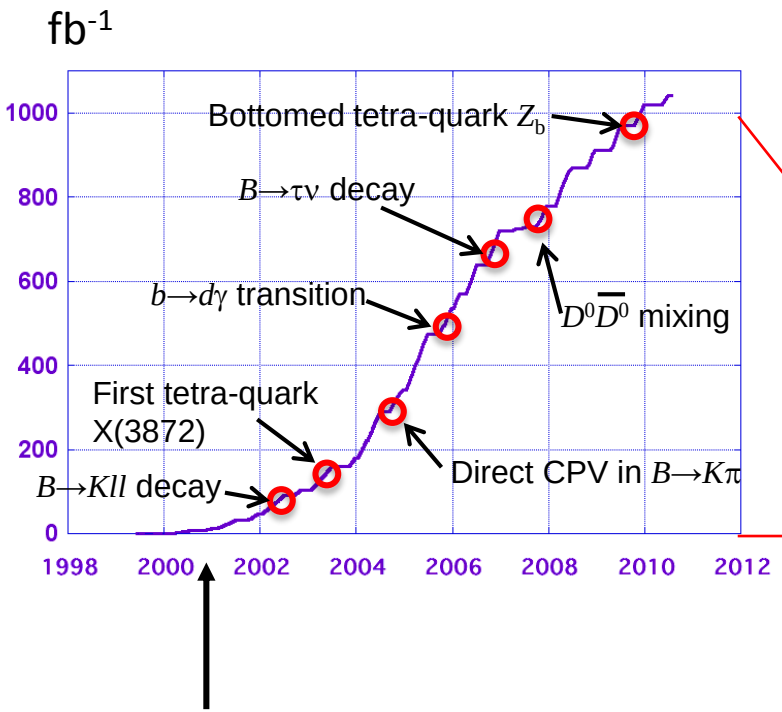
Charged Higgs

right-handed weak interaction

KEKB/Belle to SuperKEKB/Belle II

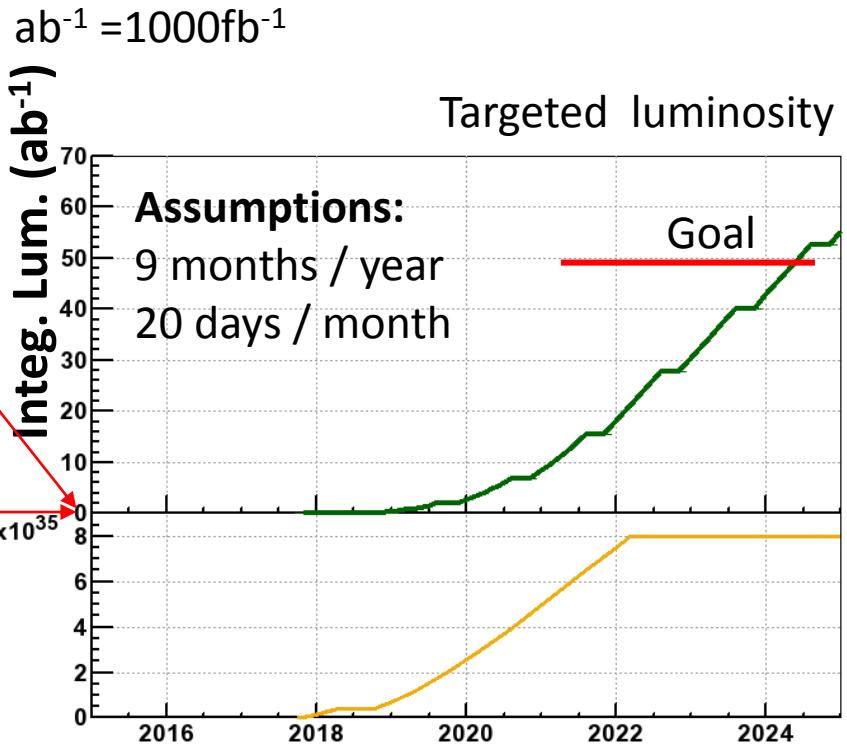
SuperKEKB/Belle II is 40 times more powerful machine compered to the previous B factory experiment, KEKB/Belle.

Belle



Discovery of CP violation in B decays

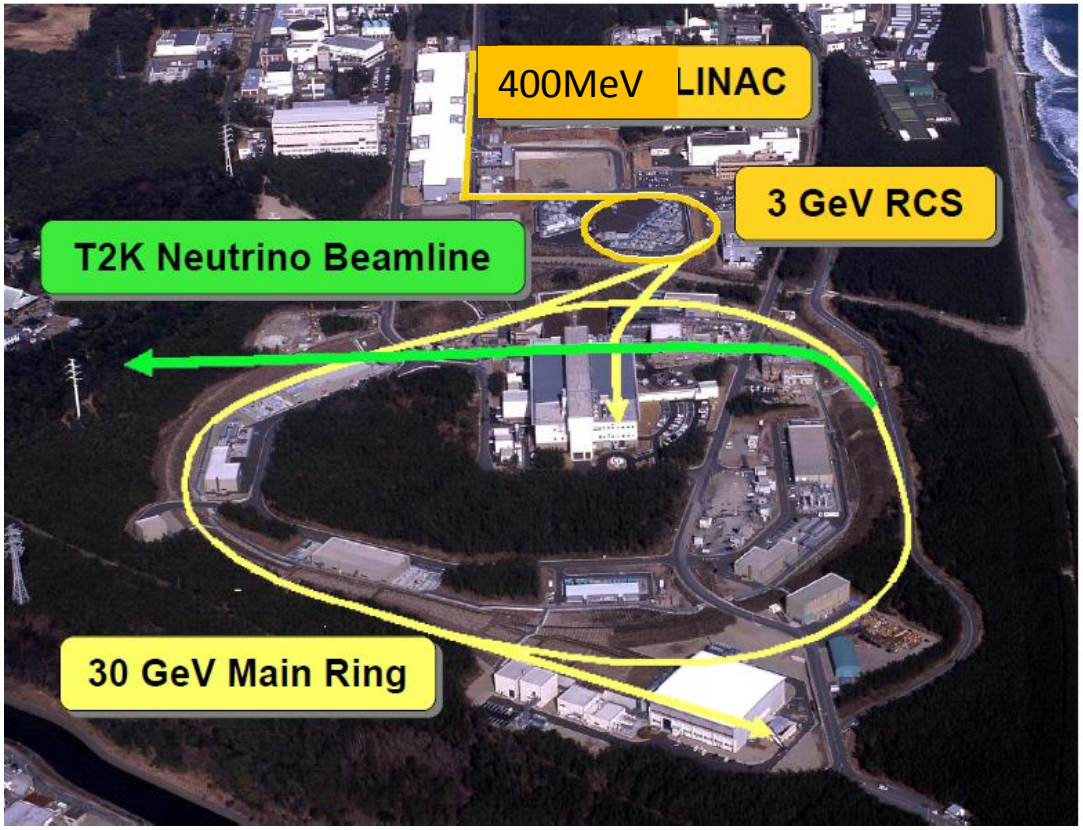
Belle II



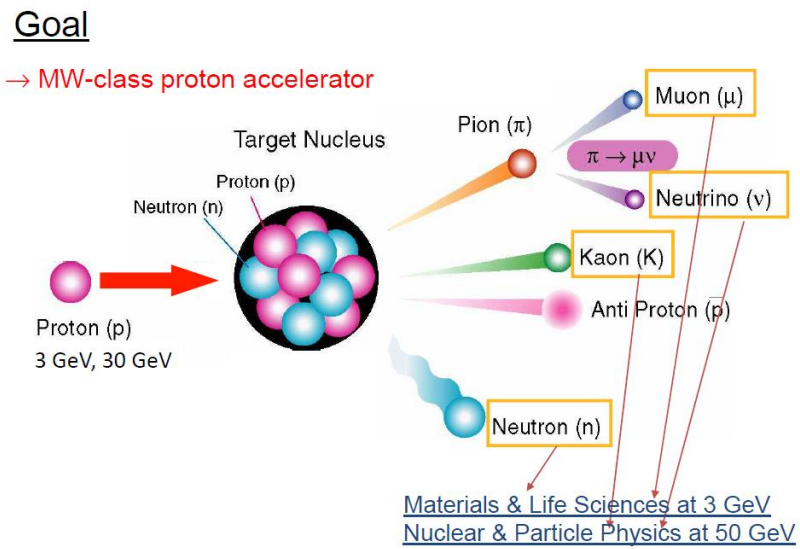
Luminosity (/cm^2/s)

J-PARC

- Located in Tokai, 60km N.E. of the KEK Tsukuba campus
- Completed in 2009
- Design goal
  - RCS: 1MW
  - MR: 750kW



Joint project of KEK & Japan Atomic Energy Agency (JAEA)



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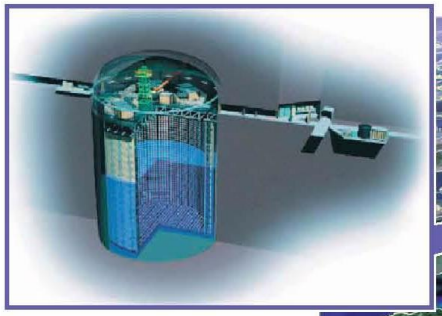
T2K Neutrino Experiment

T2K precisely confirmed Dr.Kajita's experiment, and discovered yet another phenomenon with neutrino oscillation.

2015 Noble Physics prize

Dr. MacDonald

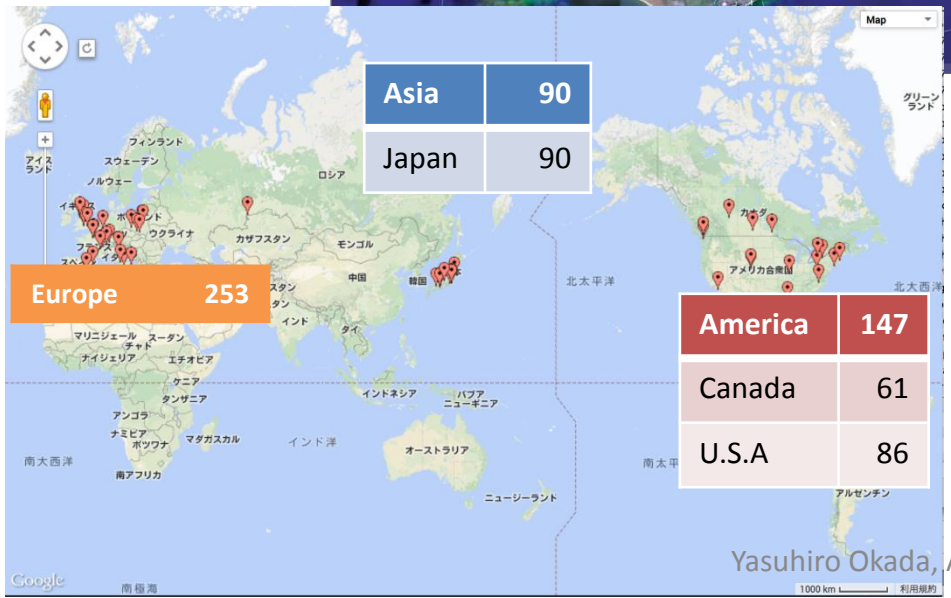
Dr. Kajita



Super-Kamiokande
(ICRR, Univ. Tokyo)

2010~ (Running)

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



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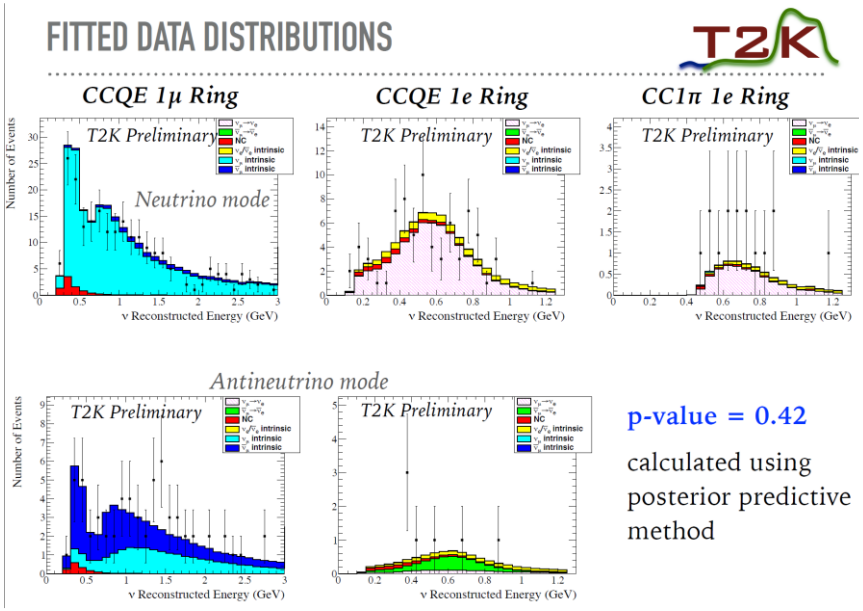
Latest Results from T2K

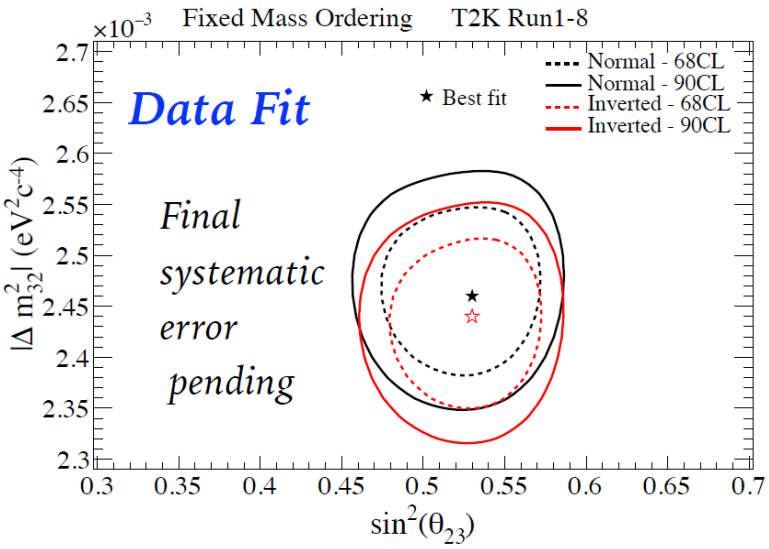


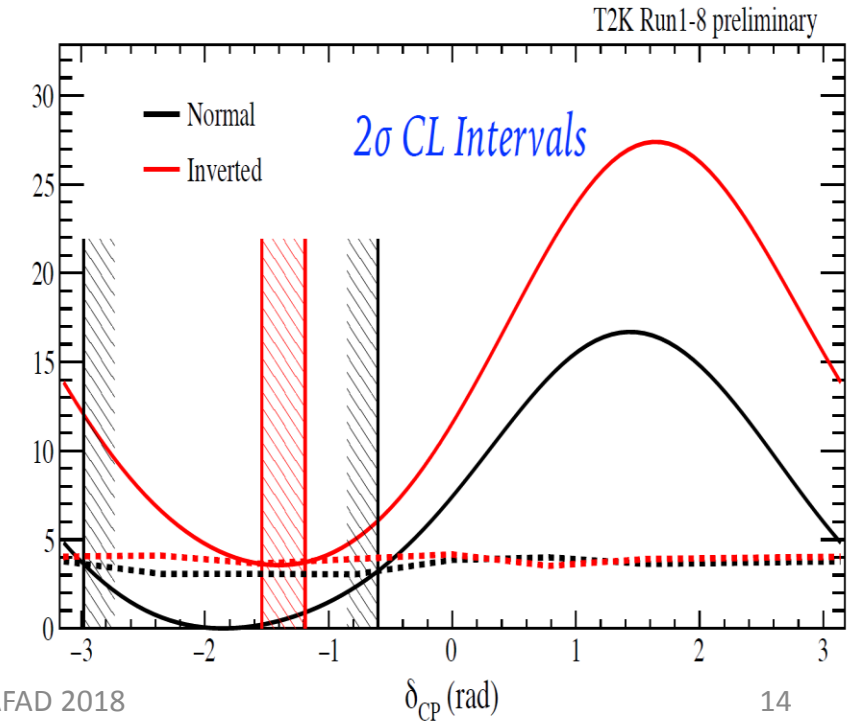
p-value = 0.42

calculated using posterior predictive method

Posterior probabilities (with reactor constraint)

	$\sin^2\theta_{23} < 0.5$	$\sin^2\theta_{23} > 0.5$	Sum
NH ($\Delta m^2_{32} > 0$)	0.193	0.674	0.868
IH ($\Delta m^2_{32} < 0$)	0.026	0.106	0.132
Sum	0.219	0.781	





- 470kW stable operation achieved
- Twice larger statistics than 2016 release
  - x1.5 POT than 2016
    - ✓ ν-beam: 14.9×10^{20} (~doubled)
    - ✓ $\bar{\nu}$-beam: 7.6×10^{20}
  - +33% higher efficiency (new sample, enlarged F.V.)
- Still consistent with maximum 23 mixing
- **CPC excluded at 95% !**
- Weak preference on NH (~87%)

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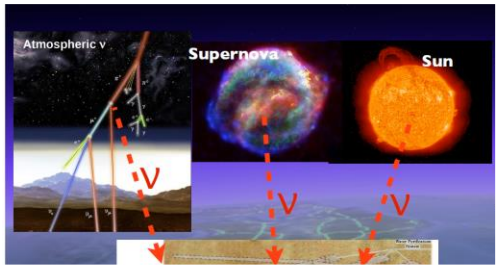
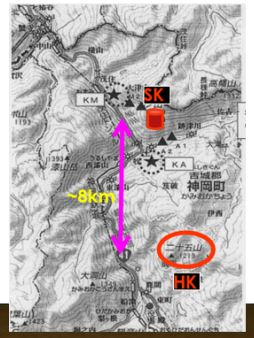
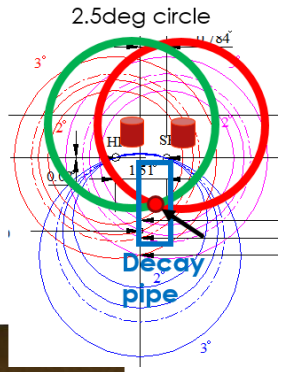
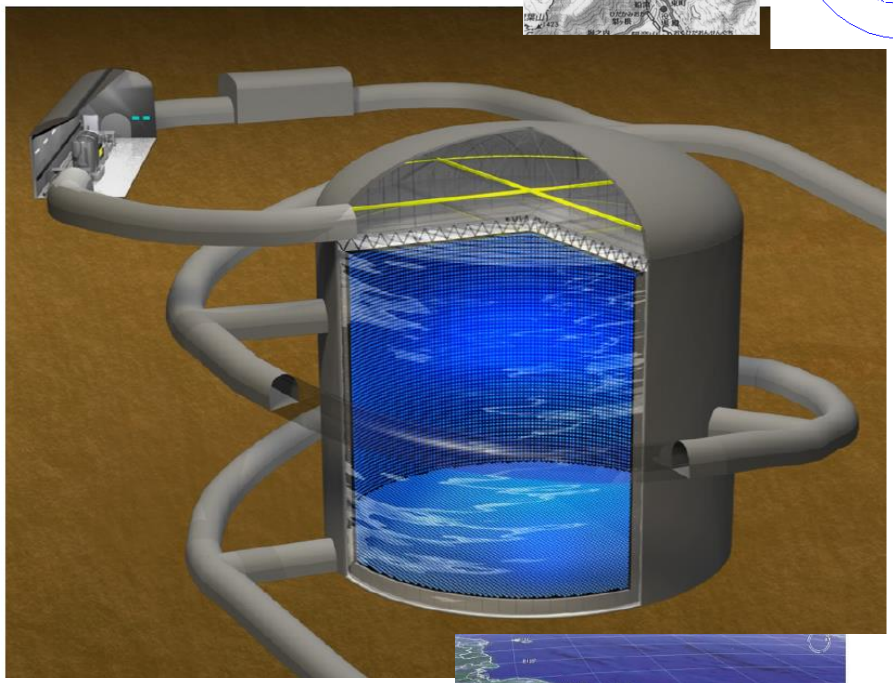
Hyper-Kamiokande (U. of Tokyo)

- Next-generation Water Cherenkov detector
  - 260kt (190kt fid. mass) x 2
  - Staging
- Detector location (candidate)
  - ~8km south of SK
  - 295km from J-PARC, @ same off-axis angle
  - 650m overburden (1755m W.E.)
- Physics goals
  - Accelerator neutrino
    - ✓ CPV in neutrino
  - Non-accelerator/Astroparticle
    - ✓ Discovery of proton decay
    - ✓ Atm-nu
    - ✓ Solar-nu
    - ✓ Supernova (relic) nu
- ICRR/UT will take primary responsibility
- Listed in the 2017 MEXT Roadmap of the Large Research Infrastructure



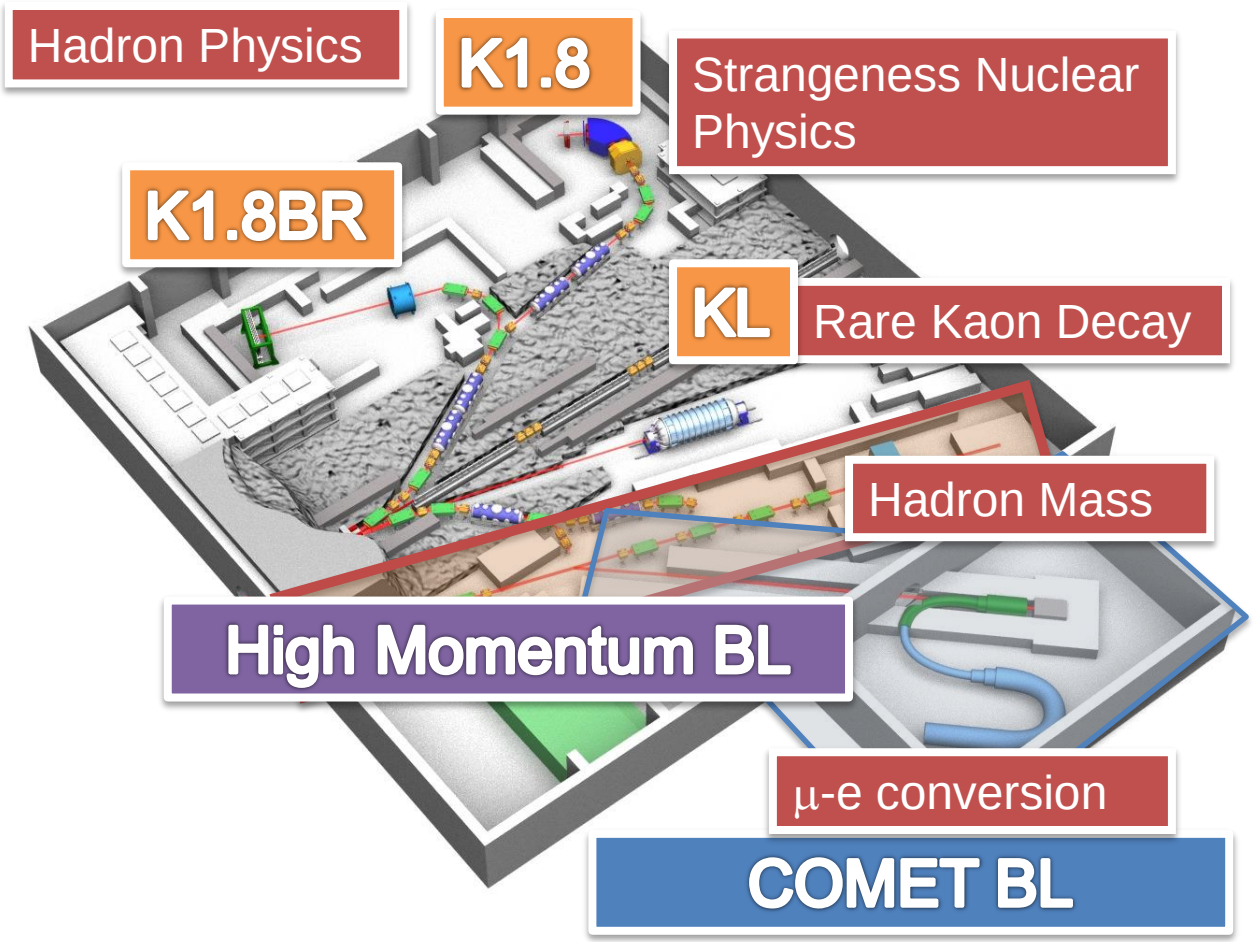






Nuclear & Particle Physics with J-PARC Hadron Beam

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->πνν
(Physics Run)

COMET (Phase I)
Search for Lepton Flavor Violation
(Under construction)

Muon g-2/EDM
(R&D phase)

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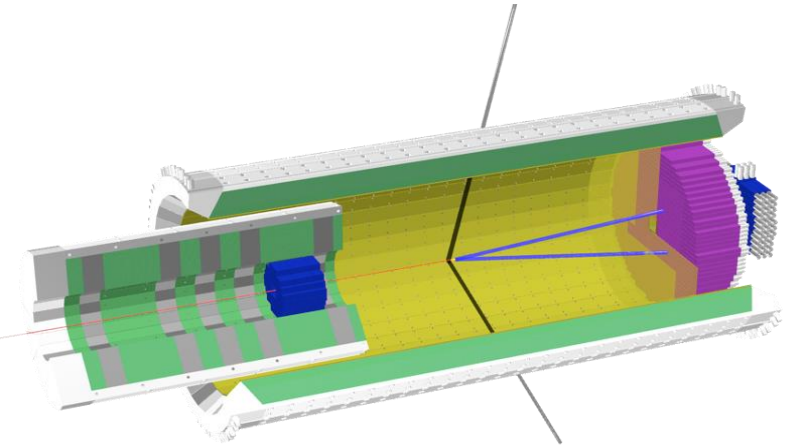
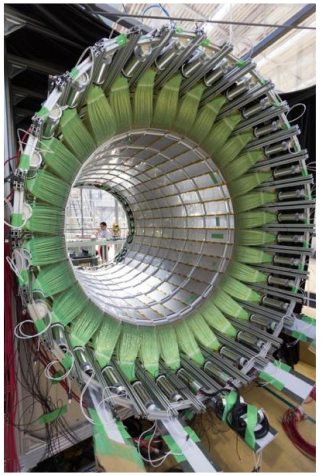
J-PARC KOTO experiment

65 participants from Japan, USA, Taiwan, Korea, Russia

$K_L \to \pi^0 \nu\bar{\nu}$

- CP symmetry breaking
- rare decay: $(3.0 \pm 0.3) \times 10^{-11}$ in the SM
- theoretically clean – best probe for physics beyond the SM



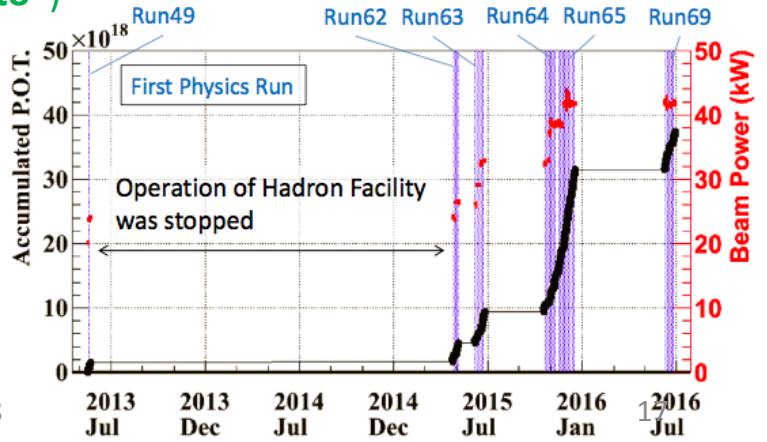


New "Inner Barrel" shower counters were successfully installed into the vacuum tank in 2016.

- **CsI calorimeter** to measure $\pi^0 \to \gamma\gamma$
- hermetic extra-particle detection ("**veto**")

- stable data taking in 2015 and 2016 :
  x20 more statistics than the 2013 data,
  to break the indirect limit (1.46 E-9).

- start the 2017 run from April 15 (Sat)
  with the 44kW slowly-extracted beam.



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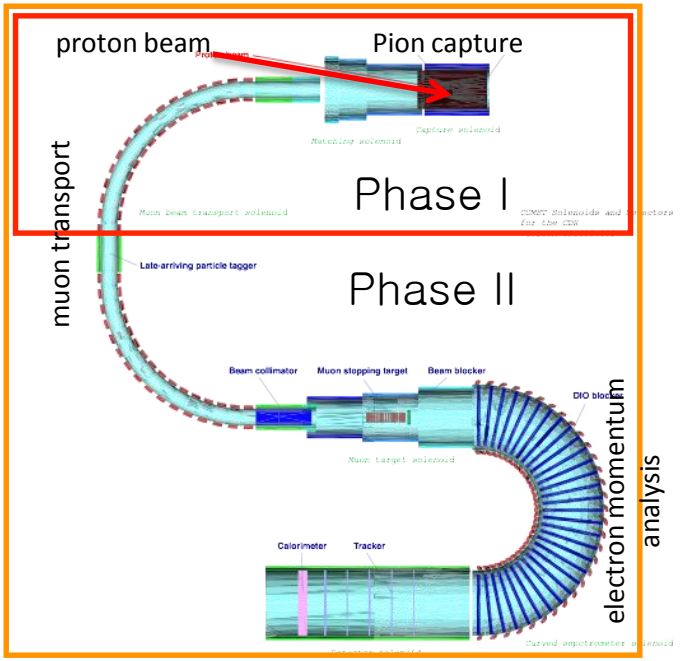
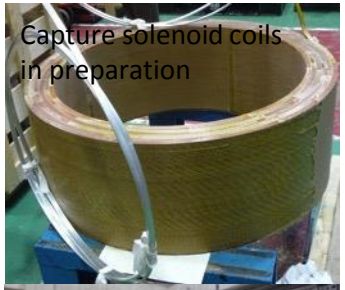
COMET

- Search for mu-e conversion with sensitivities of
  - < 10^{-14} Phase-I starts after 2019
  - < 10^{-16} Phase-II starts after2023
- J-PARC high power proton driver to generate “clean” pulsed muon beam
  - Beam extinction factor < 10-10, confirmed in the abort line measurement
  - 8GeV acceleration and extraction test in 2017 spring
- Superconducting magnet to
  - Capture pions/muons
  - Transport muons
  - and select electron momentum (in Phase II)
- Radiation Effects in Superconducting Magnet Material (RESMM’17) workshop in progress at J-PARC , 19-20/April.
  - Participants from COMET (J-PARC) and mu2e





Beam line construction started in 2016.

KEK Wako Nuclear Science Center at Riken, Wako

KEK
High Energy Accelerator Research Organization

KISS project: how are gold and platinum elements synthesized in the universe?

- nuclear properties of N=126 neutron-rich unknown isotones as progenitors in the r-process
- precise spectroscopy at newly constructed ISOL facility: KISS (KEK Isotope Separation System)

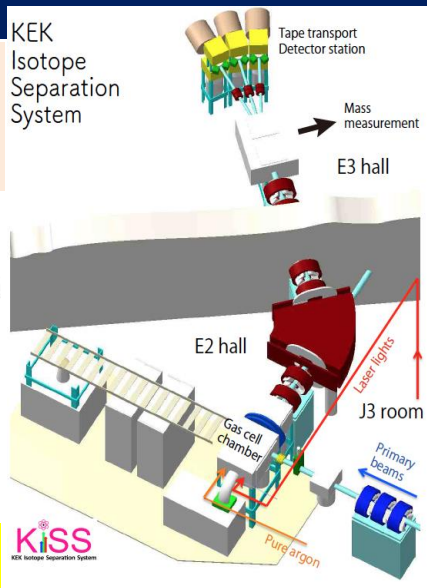
2012-2014: Construction and development of KISS
Pilot exp. of MNT reactions at GANIL

2015- : Wako Nuclear Science Center at Riken (WNSC)
User organization (SSRI-pns)
Direct mass measurement using MRTOF-MS

2016- : First PAC of KISS experimental proposals at RIBF NP-PAC
IBS(Korea)-KEK collaboration for mass and decay spectroscopies

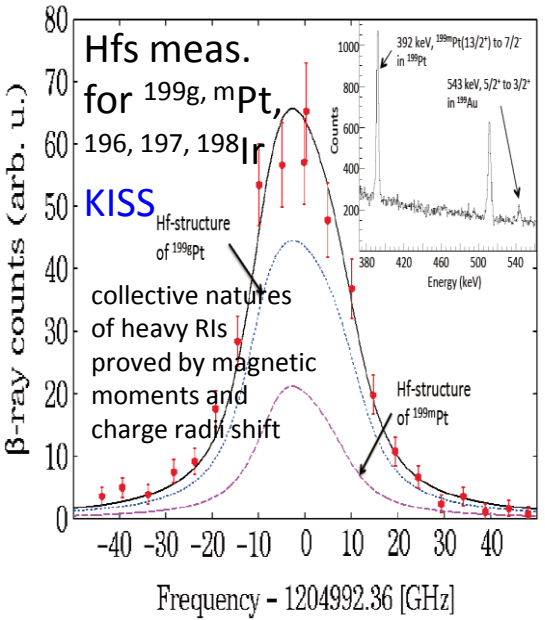
2017- : KISS stage I to stage II

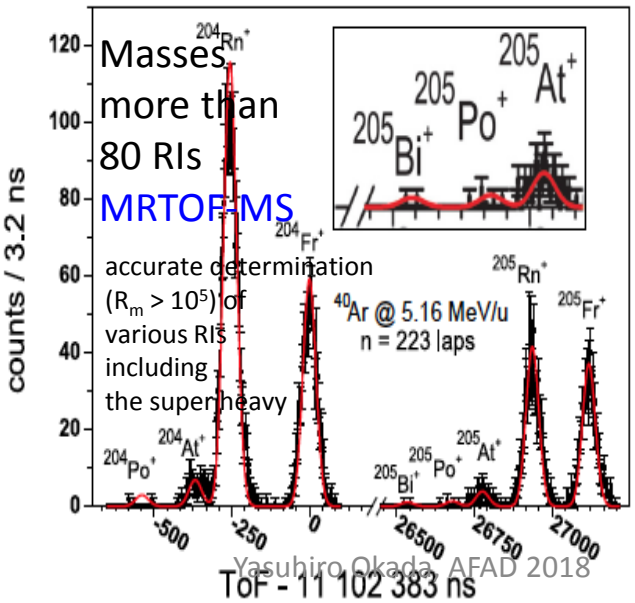
MRTOF-MS
(Multi-Reflection Time-of-Flight Mass Spectrograph)

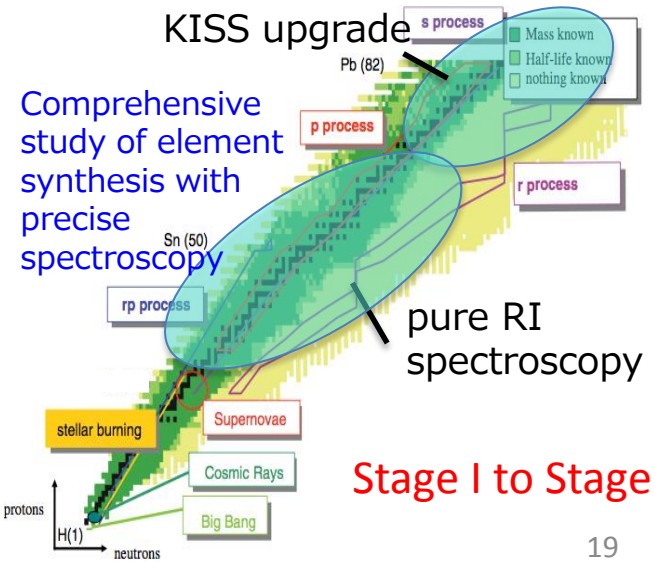


- Close collaboration with Korea (RAON/IBS)

So far… 9 subjects (approved; 6, KISS / 3, MRTOF-MS), ~60 users (7, home / 15, abroad)
22 LoIs (9, 2015 / 13, 2016) at SSRI-pns







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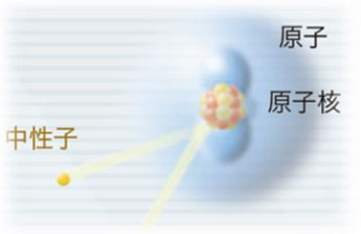
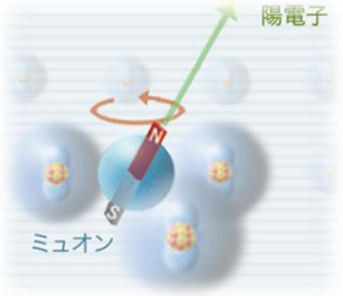
Material and Life Science facility at J-PARC

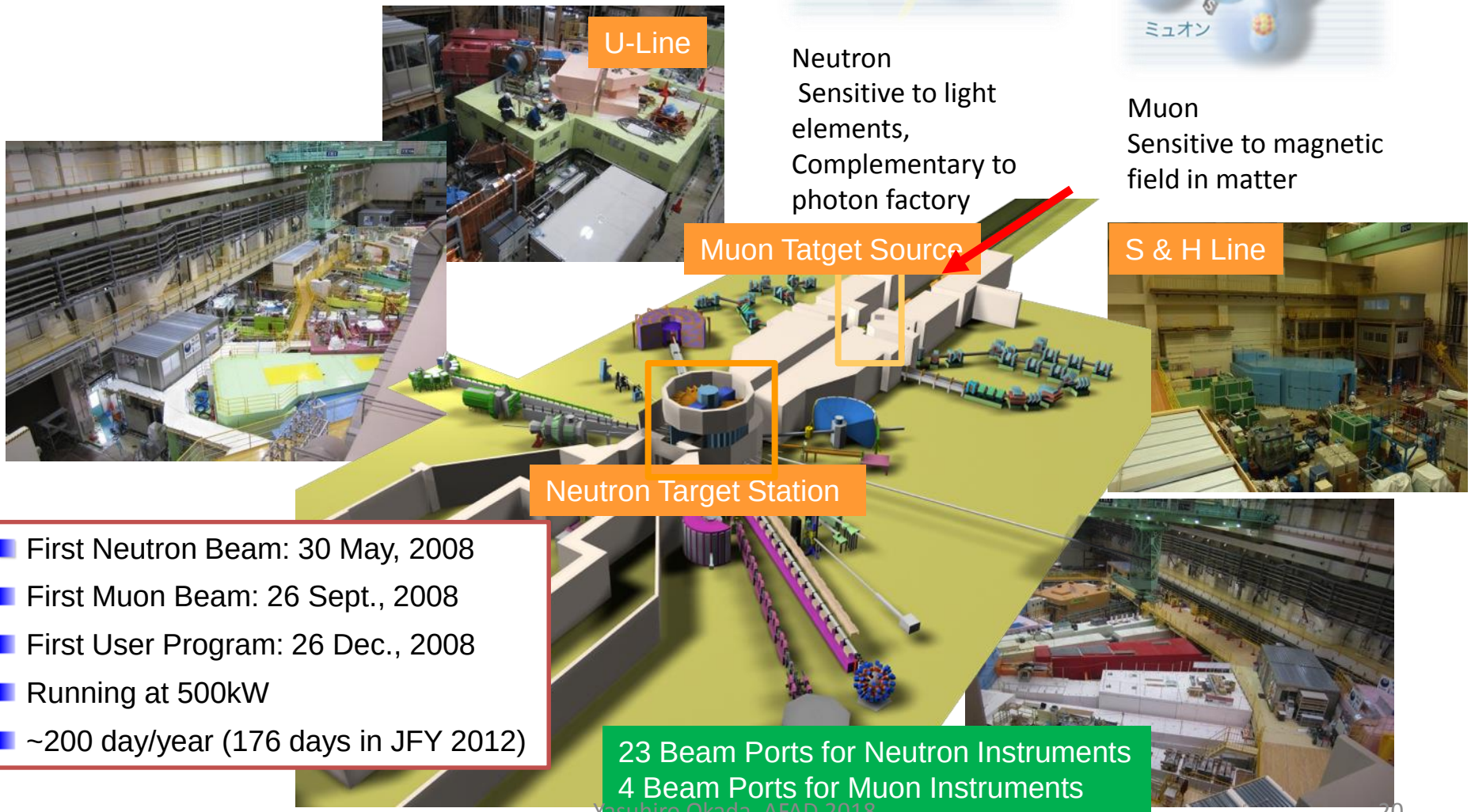
Materials and Life science using world top – class pulse neutron and muon beams



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

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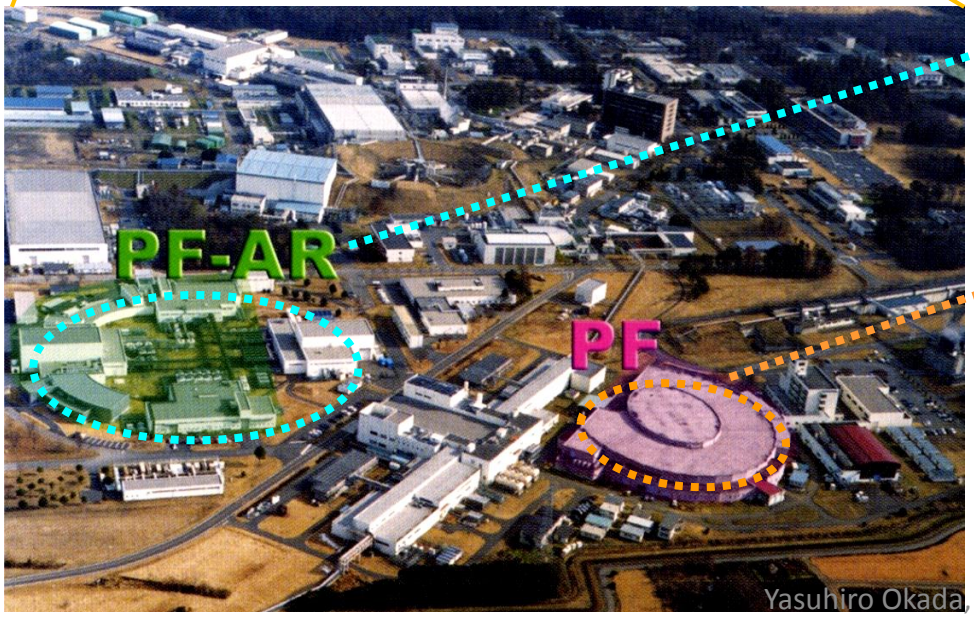
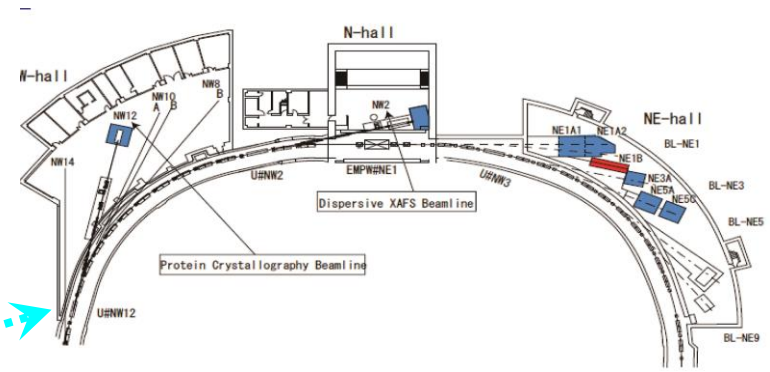
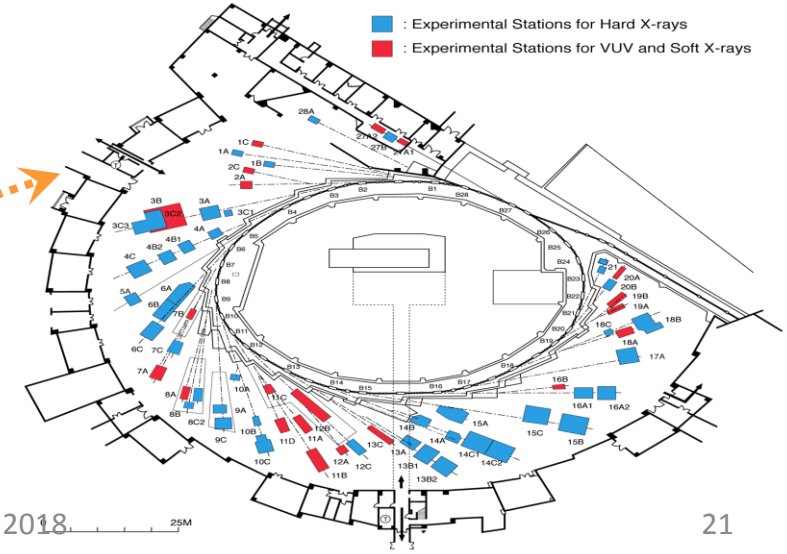
Light source facilities at KEK

PF : 2.5 GeV, 450mA e^- (since 1982)
PF-AR : 6.5 GeV, 60mA e^- (since 1997)
Exp station: ~50, Users: >3000/year







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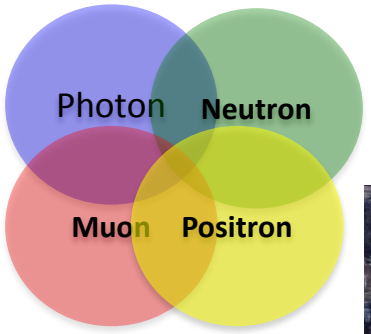
Symphonic use of photon, neutron and muon

KEK・Institute of Materials Structure Science
Structural Biology Research Center
Condensed Matter research center

IMSS
物質構造科学研究所

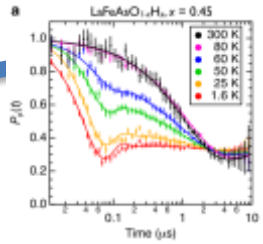


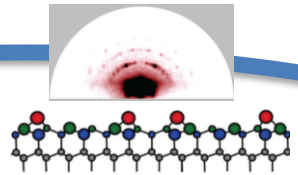
Tsukuba Campus

Photon & slow positron at PF and PF-AR

Tokai Campus

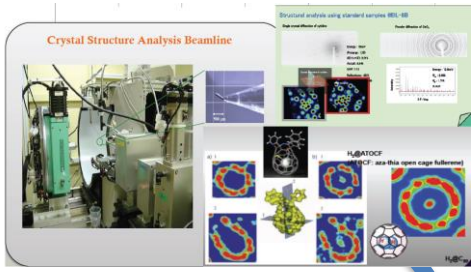
Neutron & muon at J-PARC

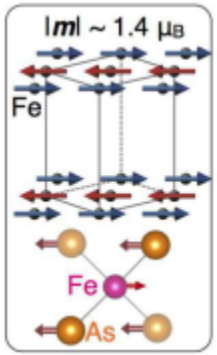


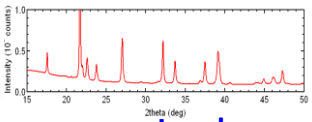


Slow positron

Surface structure







Muon

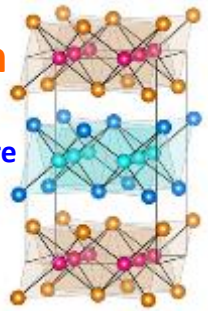
Local magnetic moment

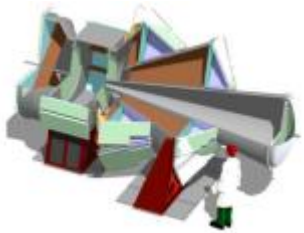
Comprehensive understanding of materials structure

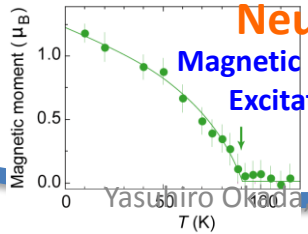
Synchrotron

Crystal structure

Electronic structure







Neutron

Magnetic structure

Excitations

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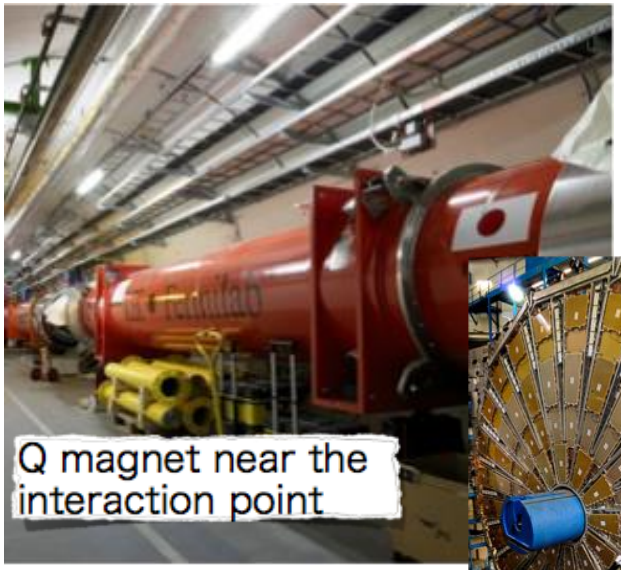
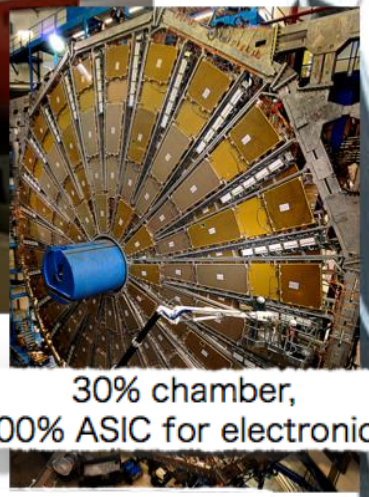
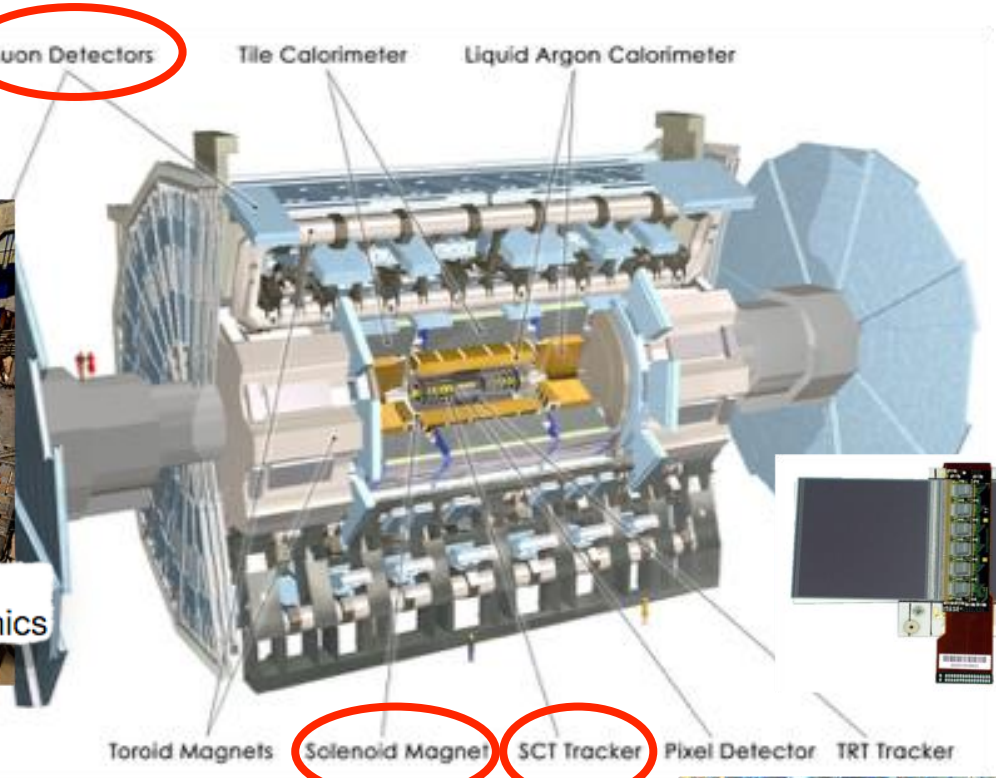
Japanese Activities at LHC/ATLAS



Q magnet near the interaction point

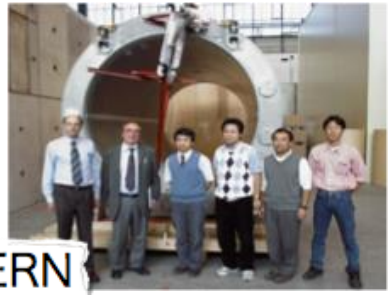


30% chamber,
100% ASIC for electronics

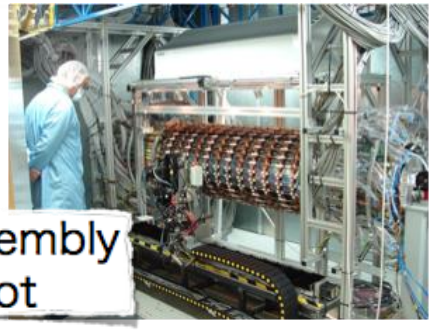


Critical contributions
- pixel/SCT operation
- muon trigger responsibility
- computing
- physics analysis
- trigger coordinator
- collaboration board chair

100% 20%



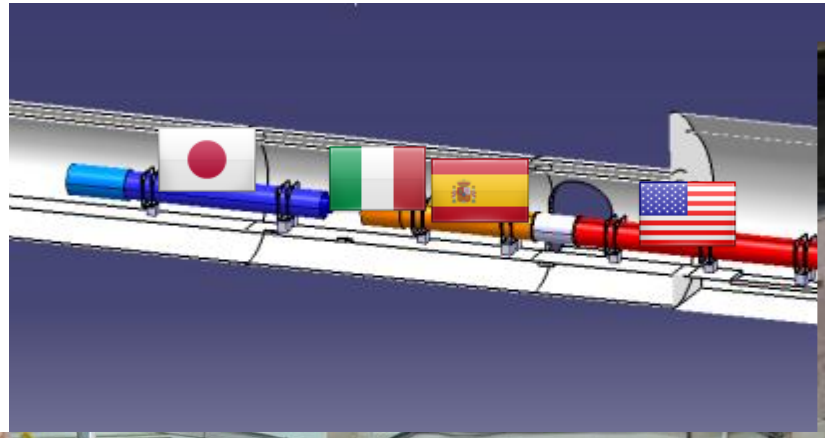
Solenoid at CERN before installation

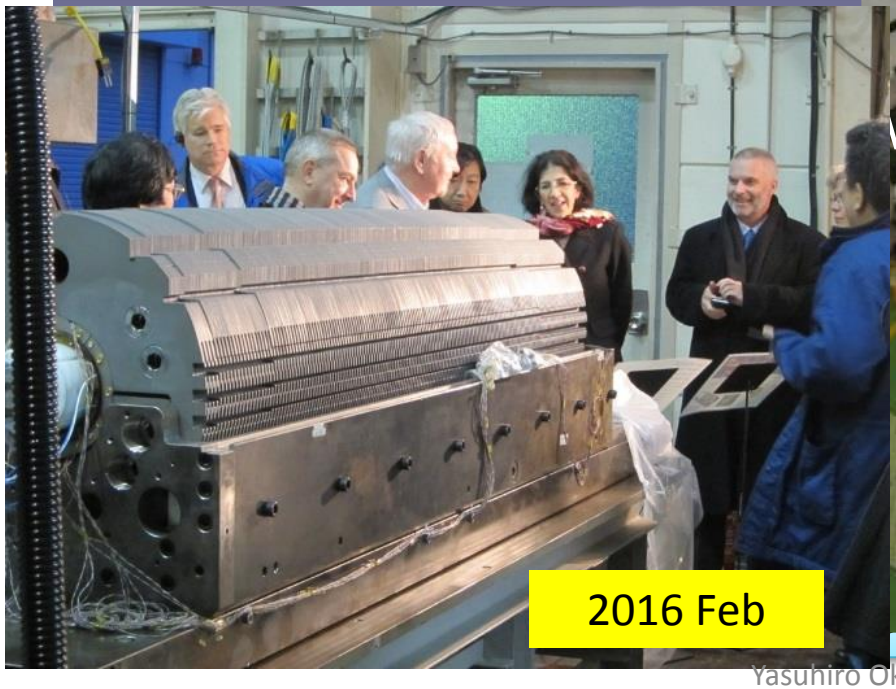


module assembly by KEK robot

Contribution to HL-LHC

2m Model coil production and test at KEK





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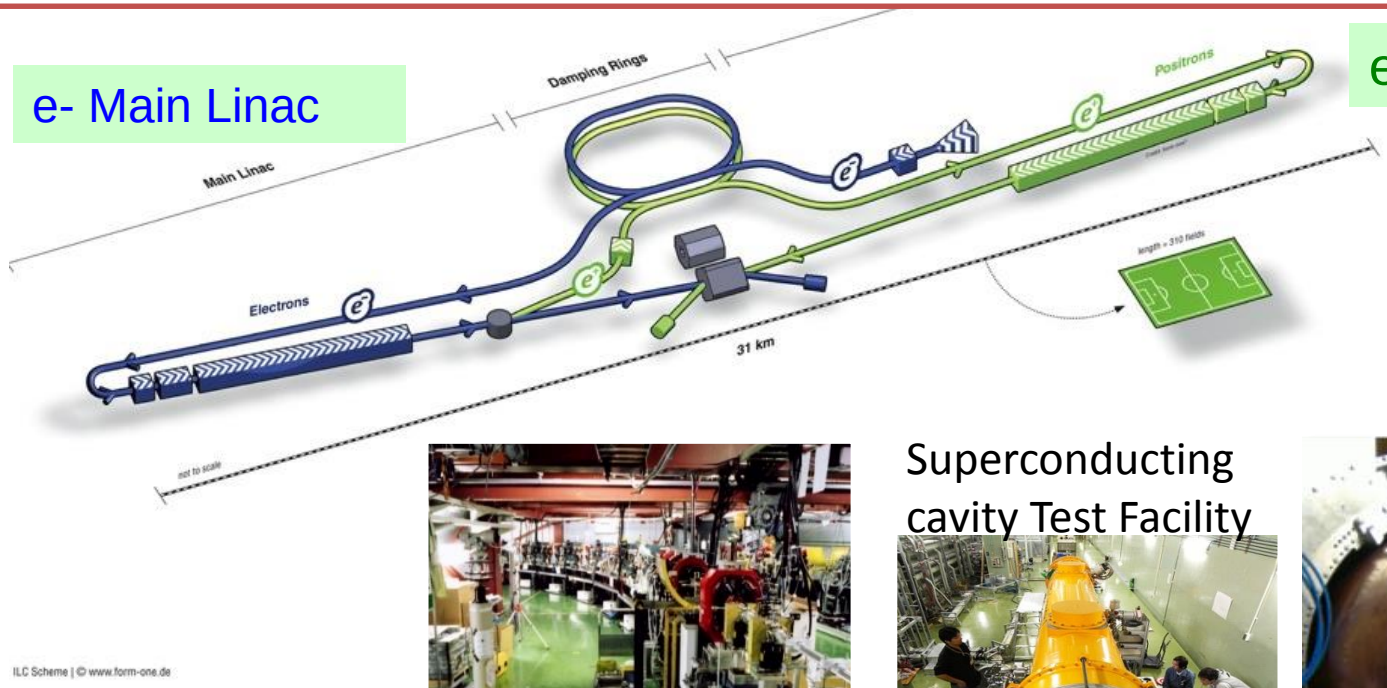
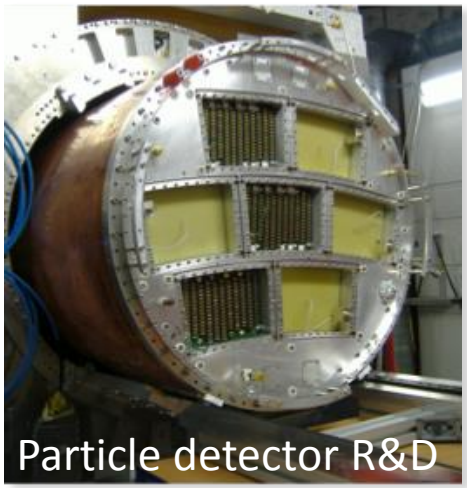
International Linear Collider

- 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.



Accelerator Test Facility

Superconducting cavity Test Facility


Particle detector R&D

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

Recent developments

- MEXT, Japanese Government set up ILC Advisory Panel in 2014, investigating issues to judge hosting the ILC in Japan.
- DOE-MEXT Discussion Group on the ILC was formed in 2016. US-Japan cooperative R&D for cost reduction of the ILC was started aiming for improvement of the Superconducting RF accelerator technology.
- A consensus has been built worldwide to start the ILC as a Higgs factory with 250GeV CM energy .

  (The cost can be lower up to 40% while energy extendibility is kept)

International Committee for Future Accelerators (ICFA) released its statement supporting 250 GeV ILC in November 2017.

"ICFA thus supports the conclusions of the Linear Collider Board (LCB) in their report presented at this meeting and very strongly encourages Japan to realize the ILC in a timely fashion as a Higgs boson factory with a center-of-mass energy of 250 GeV as an international project, led by Japanese initiative."

http://icfa.fnal.gov/wp-content/uploads/ICFA-Statement-Nov2017.pdf
http://icfa.fnal.gov/wp-content/uploads/LCB-Short-Conclusion-Nov2017.pdf

*The Japanese HEP community (JAHEP) statement in July 2017
http://www.jahep.org/files/JAHEP-ILCstatement-170816-EN.pdf

Possible timeline in Japan

- The advisory panel in MEXT is now investing the revised plan of the ILC. We expect to see some conclusion from the panel in a few months timescale, which will be examined by the Science Council of Japan (SCJ).

- If the conclusion is favorable for pursuing the ILC in Japan, then this year becomes a real critical time for realization of the ILC.

- In parallel, discussions between the Japanese Government and foreign partners are in progress beyond US-Japan.

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A visit to Europe by a Japanese delegation

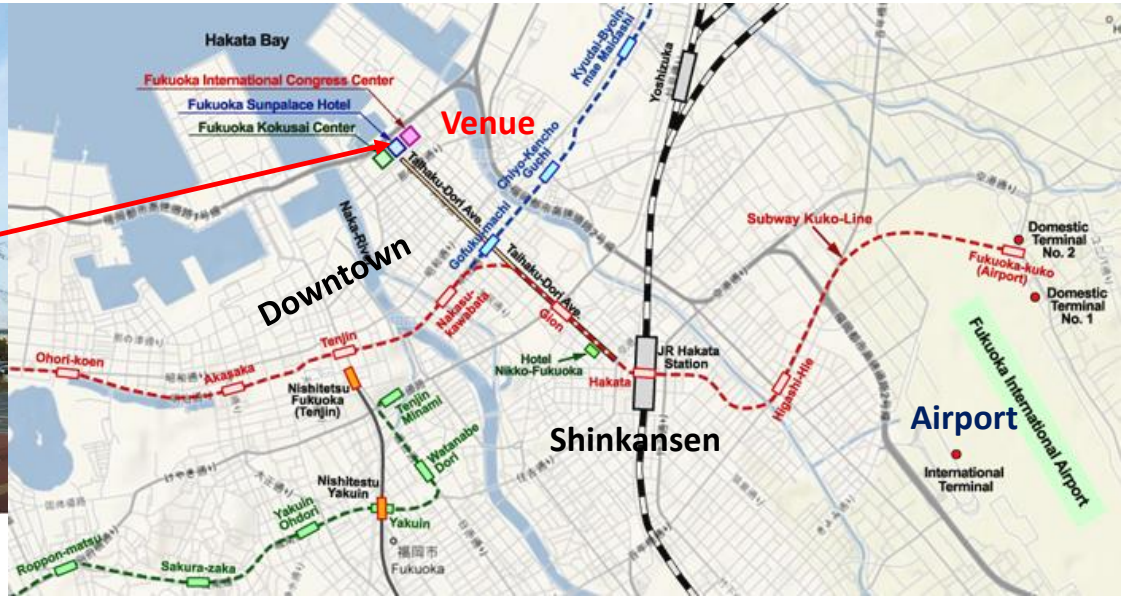
- A Japanese delegation consisting of Diet members, a government official, representatives from the industrial sector, and researchers visited Europe early January 2018 to discuss cooperation on the ILC project.

- Several meetings were held in Paris, France (January 9-10) and in Berlin, Germany (January 11).

- The meetings were quite successful in both countries. It was agreed that we should continue discussions on the ILC at the Diet/Parliament member level, the government official level, the funding agency/laboratory level, and the researcher level. The French (German) counterpart to Japanese representatives at each level was identified at these meetings.

ALCW2018 in Fukuoka, from May 28 to June 1

- Co-hosted by Kyushu-U, KEK, ACFA/AsiaHEP, and LCC
- Venue: Fukuoka International Congress Center
  - http://www.marinemesse.or.jp/eng/congress/
  - Located in the bay area close to the downtown, Fukuoka international airport, and Hakata station.



- Webpage: https://agenda.linearcollider.org/event/7826/
- Registration will be open by mid February

ALCW2018 is the next in a series of regional linear collider workshops held around the world. The purpose of the workshop is the continued development of the physics case, and the advancement of detector and accelerator designs for a high energy linear electron-positron collider.

Summary

- KEK has diverse science programs from particle and nuclear physics to materials and life sciences based on large accelerator facilities.
- In SuperKEKB/Belle II, collision experiments are about to begin aiming for discovery of new physics.
- KEK is also preparing for future. KEK is making efforts to realize the ILC starting as a Higgs factory with worldwide HEP communities.