Roadmap for HEP in Japan

Yasuhiro Okada (KEK)

Community Planning Meeting (CMP2012)

October 11, 2012, Fermilab

content

- Present status of HEP projects in Japan
- Future planning by the Japanese HEP community and KEK

Electron machines in Tsukuba and proton machines in Tokai

KEK

Tokai

Tsukuba

Sapporo

Honshu

Nagoya

Kobe

Osaka

Chiba

Fukuoka

Shikoku

Kyushu

Korea

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38°24'54.24" N 139°30'09.59" E elev 42 m

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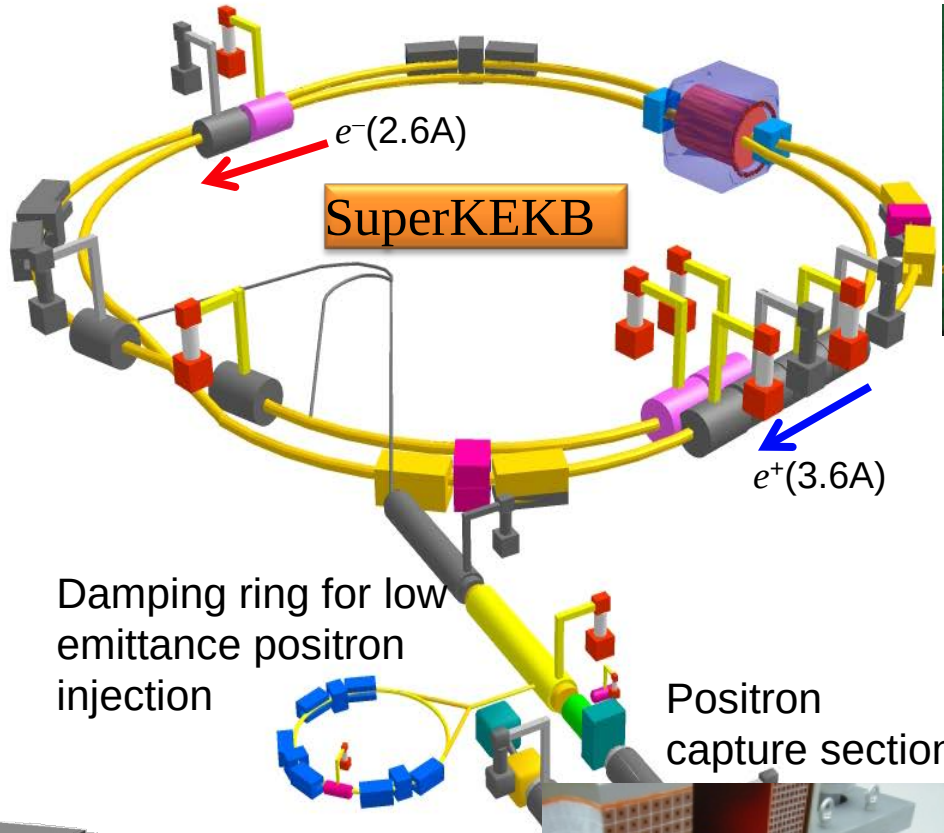
Eye alt 2182.40 km

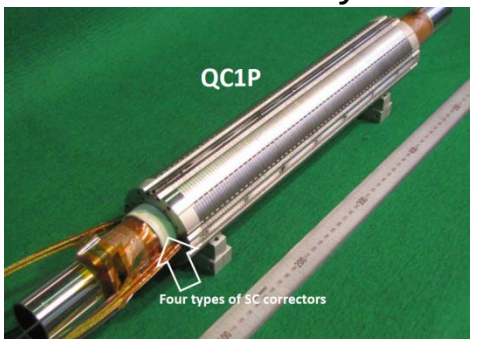
KEKB upgrade to SuperKEKB

Beam commissioning scheduled in 2015

Low emittance lattice



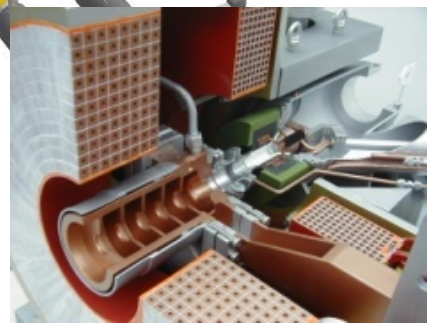
IR with β_y*=0.3mm
SC final focus system

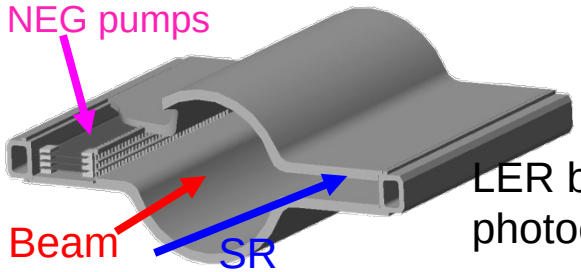


Add RF systems for higher beam current

Damping ring for low emittance positron injection

Positron capture section





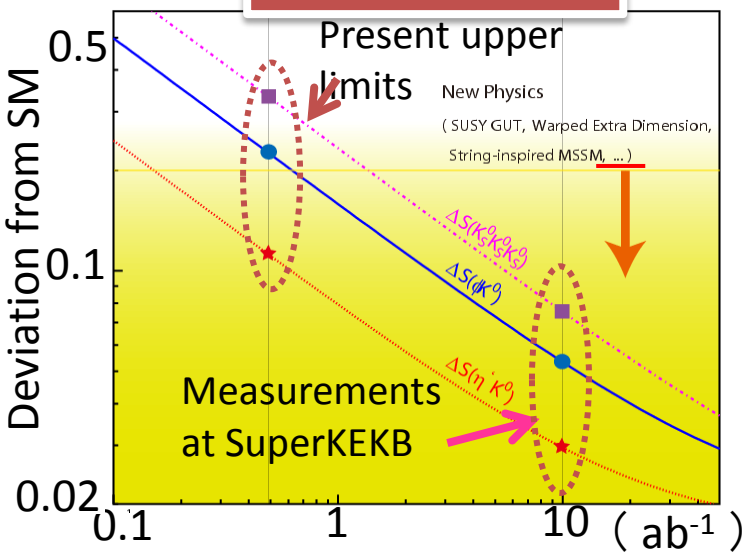
LER beampipe to suppress photoelectron instability

Target: L = $8 \times 10^{35}/cm^2/s$

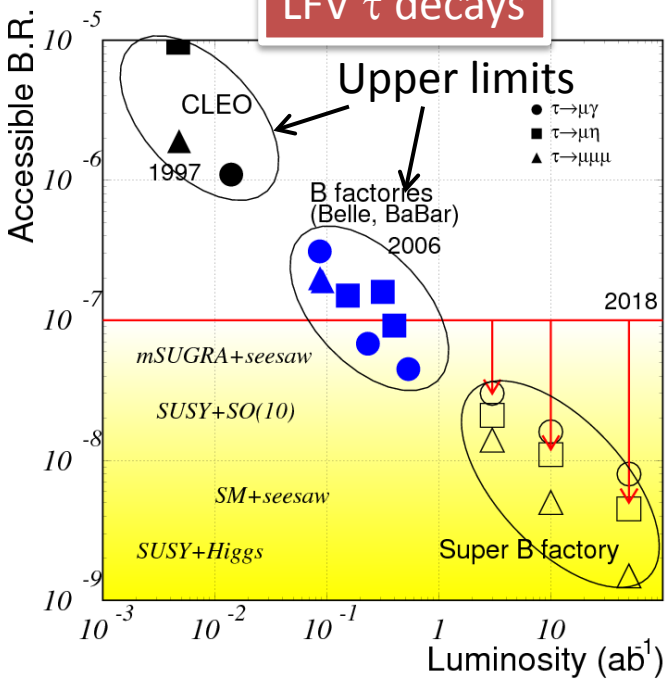
Physics at SuperKEKB

- If New Physics scale is at TeV region,
  - It is natural to assume that the NP effects are seen in $B/D/\tau$ decays.
  - Flavor structure of new physics?
  - CP violation in new physics?
- Otherwise…
  - Search for deviations from SM in flavor physics will be one of the best ways to find new physics.

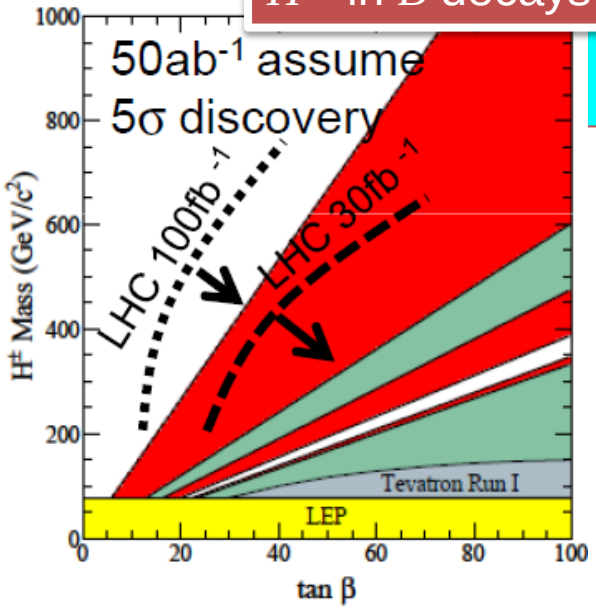
CPV in new FCNC



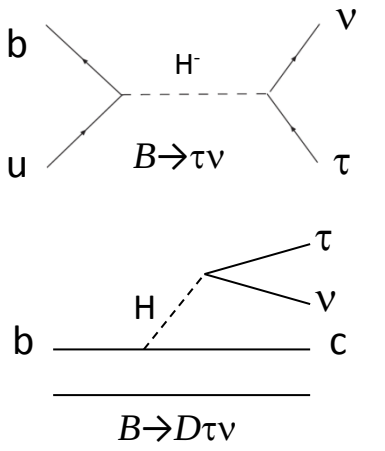
LFV τ decays

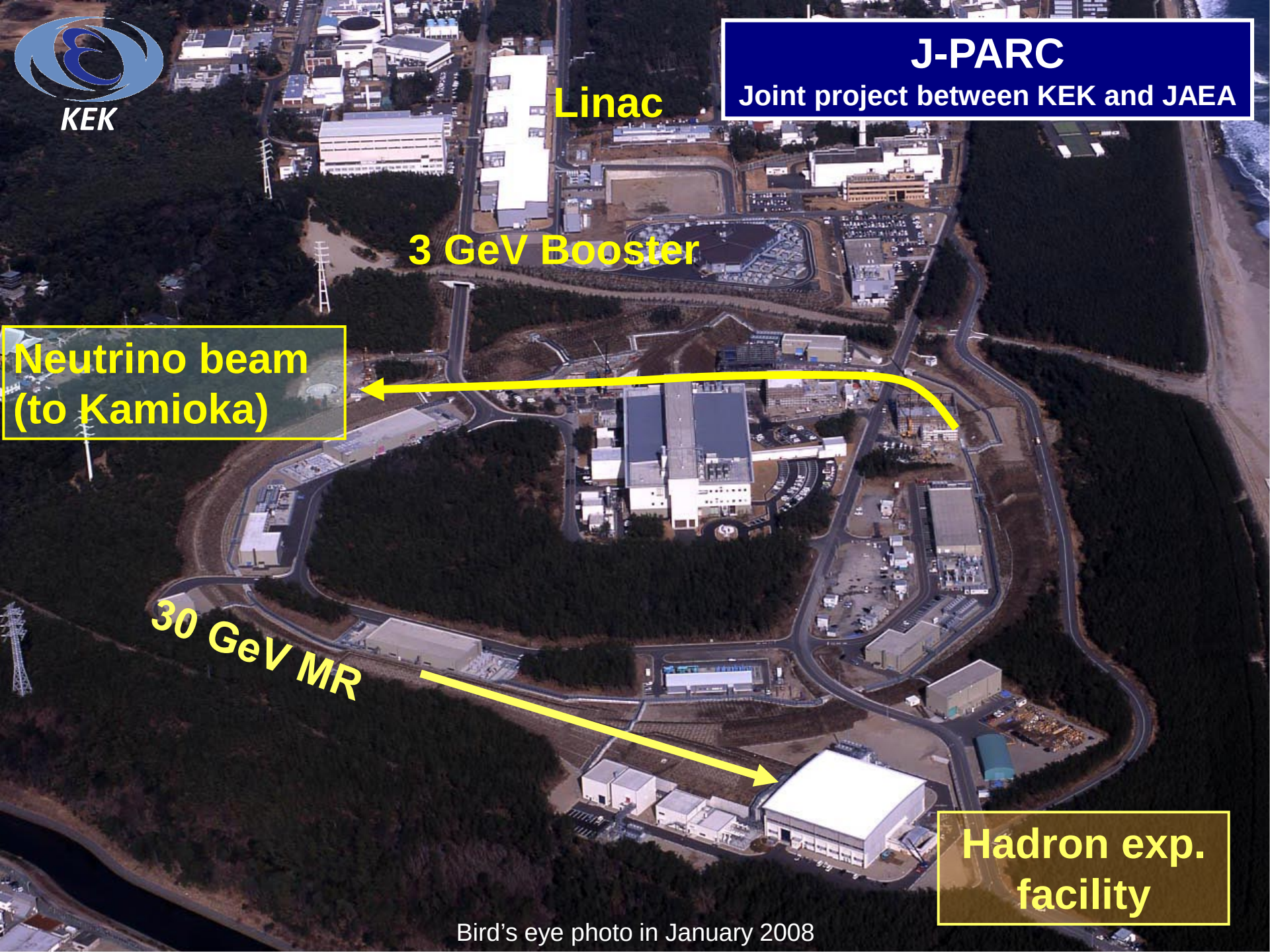


$H^{\pm}$ in B decays



B->τν: H-b-u coupling
B->Dτν : H-b-c coupling





Bird's eye photo in January 2008

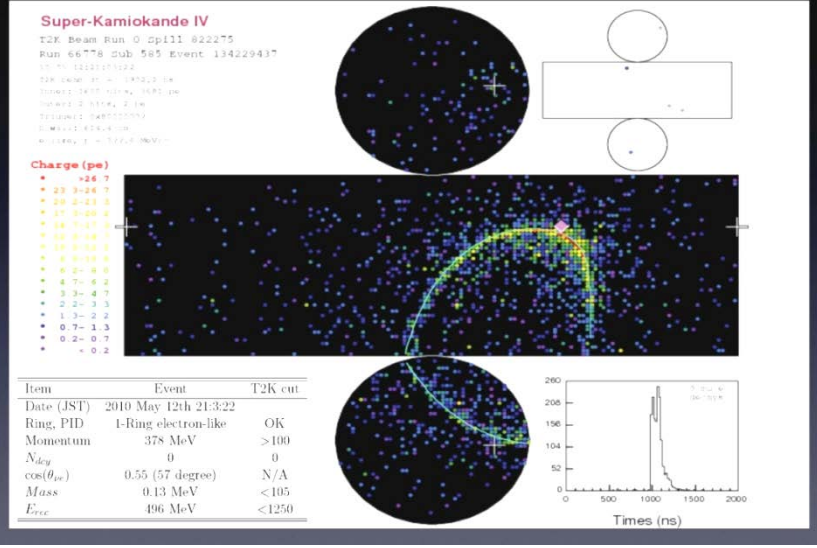
T2K : Long Baseline Neutrino Experiment

Super-Kamiokande
(ICRR, Univ. Tokyo)

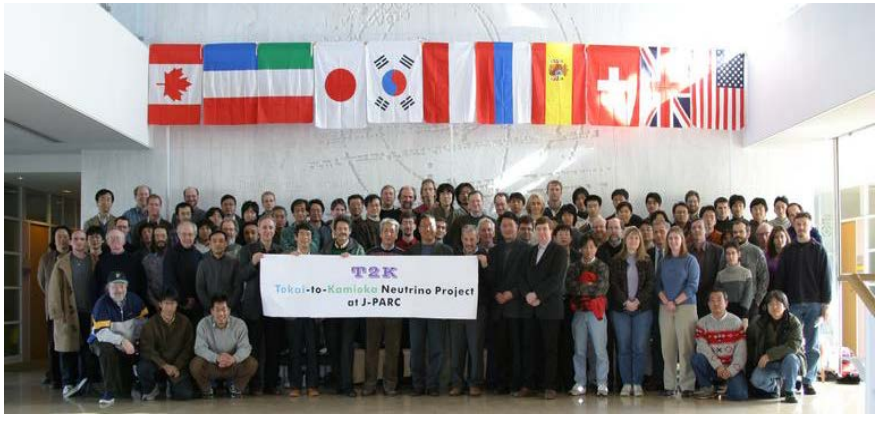
J-PARC Main Ring
(KEK-JAEA, Tokai)

T2K ν_e CC signal candidate (2010a)

Signal candidate event passing all cuts



Item	Event	T2K cut
Date (JST)	2010 May 12th 21:3:22	
Ring, PID	1-Ring electron-like	OK
Momentum	378 MeV	>100
N_{dcy}	0	0
$\cos(\theta_{ve})$	0.55 (57 degree)	N/A
$Mass$	0.13 MeV	<105
E_{rec}	496 MeV	<1250

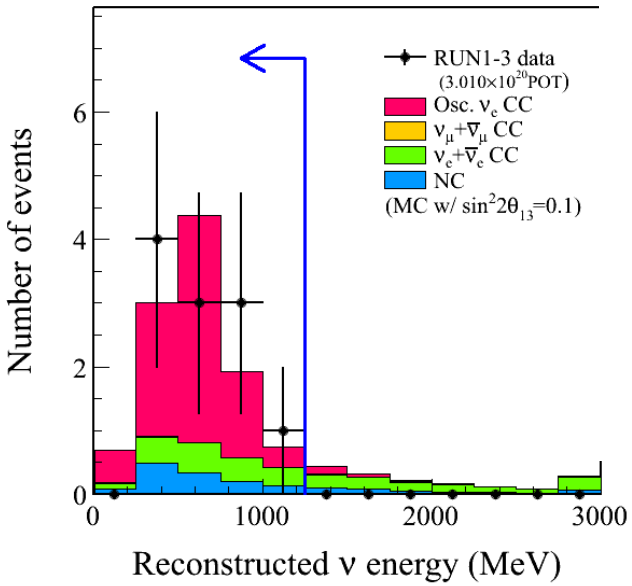


~500 members from 12 Countries:
Japan, US, Canada, France, UK, Switzerland,
Poland, Korea, Russia,
Spain, Italy, Germany

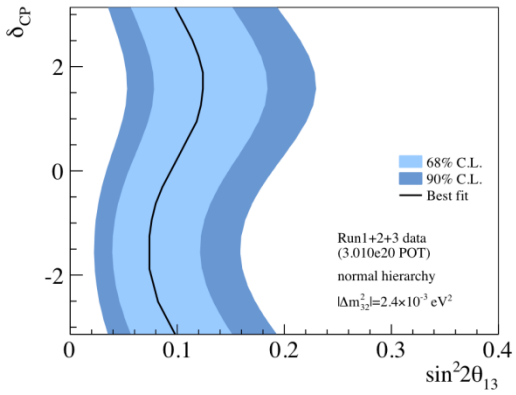
Latest Result of $\nu_\mu \rightarrow \nu_e$ from T2K

All the plots here are preliminary.

11events 3.01x10^{20} POT

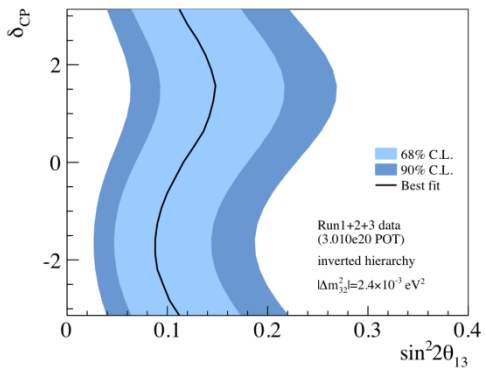


Normal hierarchy



$$\sin^2 2\theta_{13} = 0.094^{+0.053}_{-0.040} \quad @\delta_{CP} = 0$$

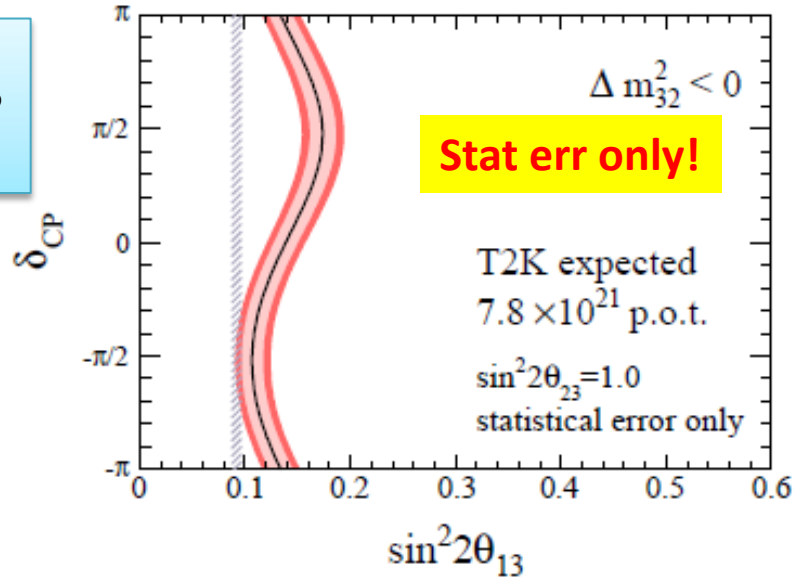
Inverse hierarchy



$$\sin^2 2\theta_{13} = 0.116^{+0.063}_{-0.049} \quad @\delta_{CP} = 0$$

Improvement of both reactor and accelerator experiments will provide first handle on the CP violating complex phase δ_{CP}.

Expectation with ~50 times more data (750kWx 5x10^{7}s)

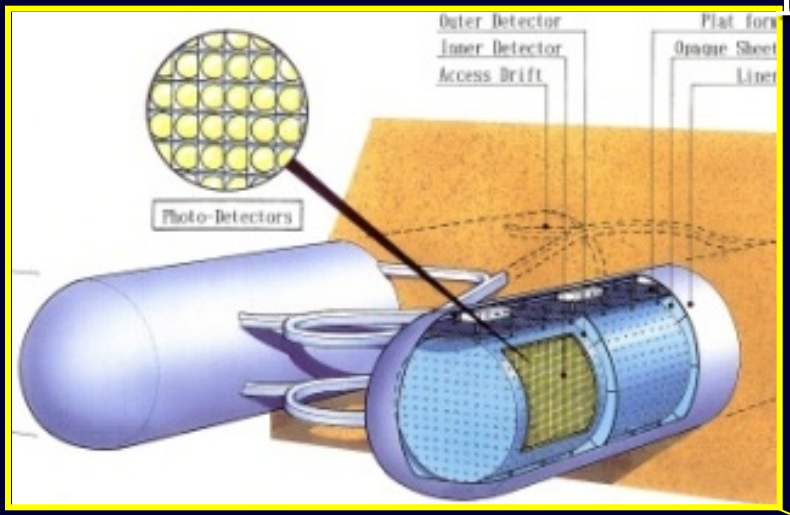


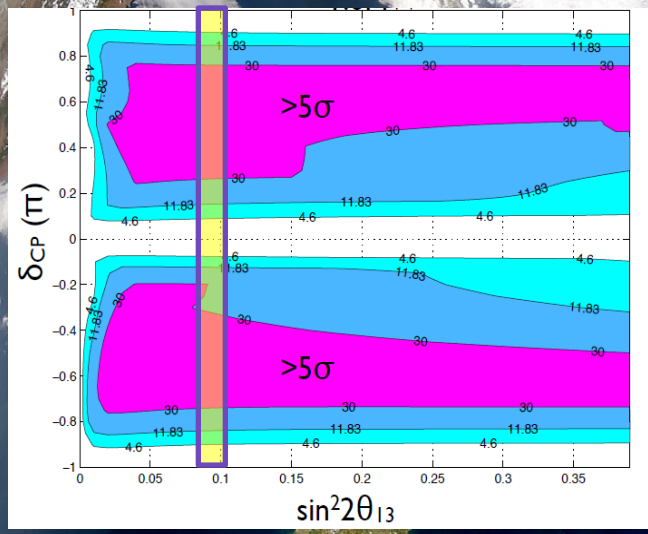
Expected beam power

May 2012	2014	2018
190kW	300kW	750kW

Next ν program at J-PARC

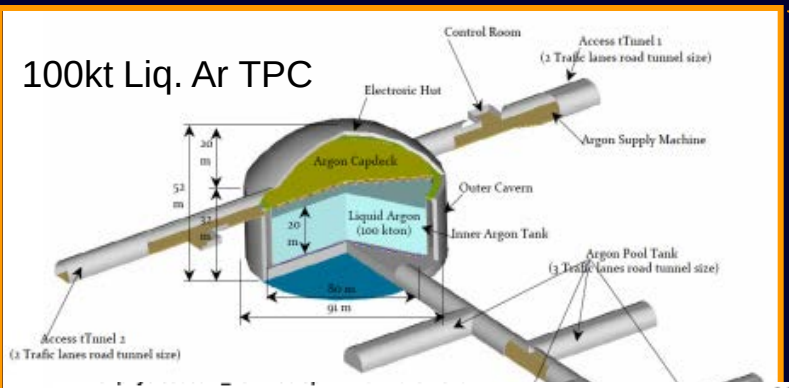
Kamioka L=295km OA=2.5deg

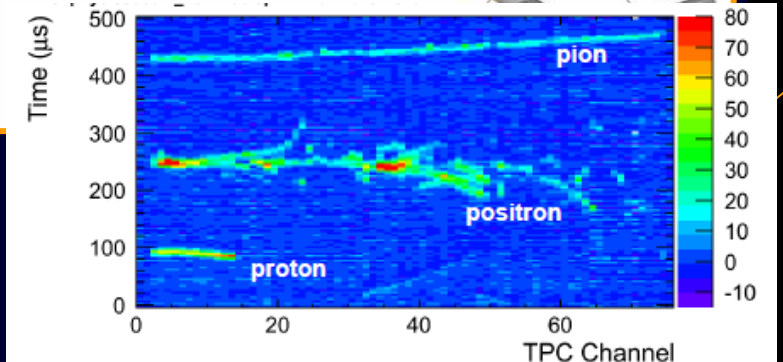




Okinoshima L=658km OA=0.78deg

100kt Liq. Ar TPC





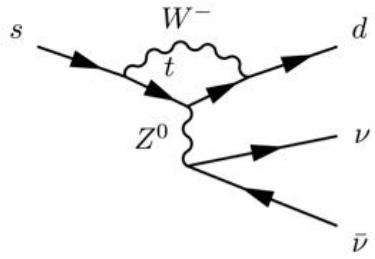
J-PARC
→1.7MW

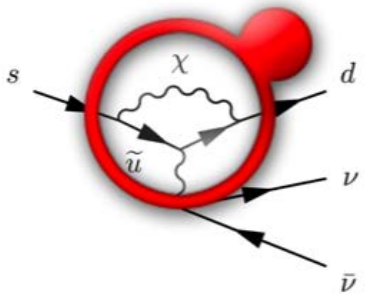
Hope to start construction ~2018

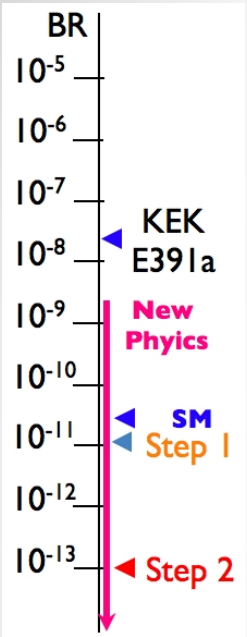
Rare Kaon Decay

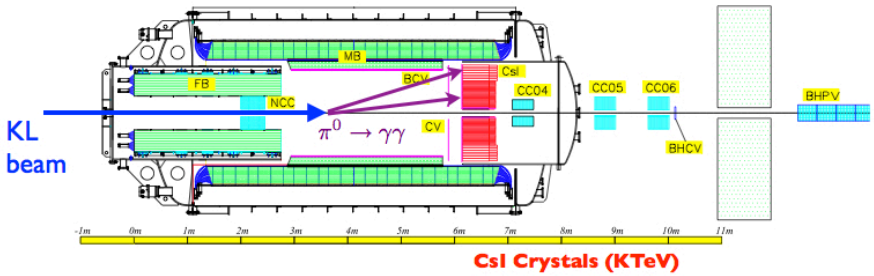
J-PARC HADRON HALL

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



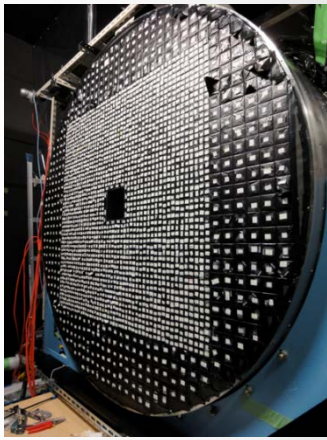






CV

CsI



KL beam line
(KL decay in flight)

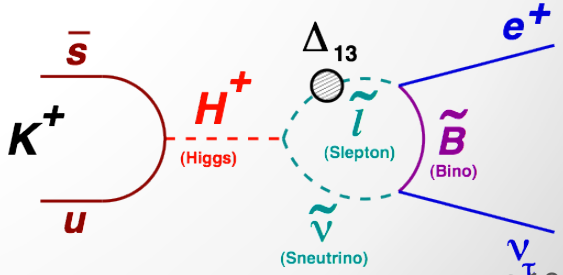
K1.1BR beam line
(K+ decay at rest)

E36 (LFU)

$$\Gamma(K^+ \to e^+\nu)/\Gamma(K^+ \to \mu^+\nu)$$

SM: (2.477±0.001)·10-5

$$R_K = \frac{\Sigma_i\, \Gamma(K \to e\nu_i)}{\Sigma_i\, \Gamma(K \to \mu\nu_i)} \simeq \frac{\Gamma_{SM}(K \to e\nu_e) + \Gamma(K \to e\nu_\tau)}{\Gamma_{SM}(K \to \mu\nu_\mu)}$$

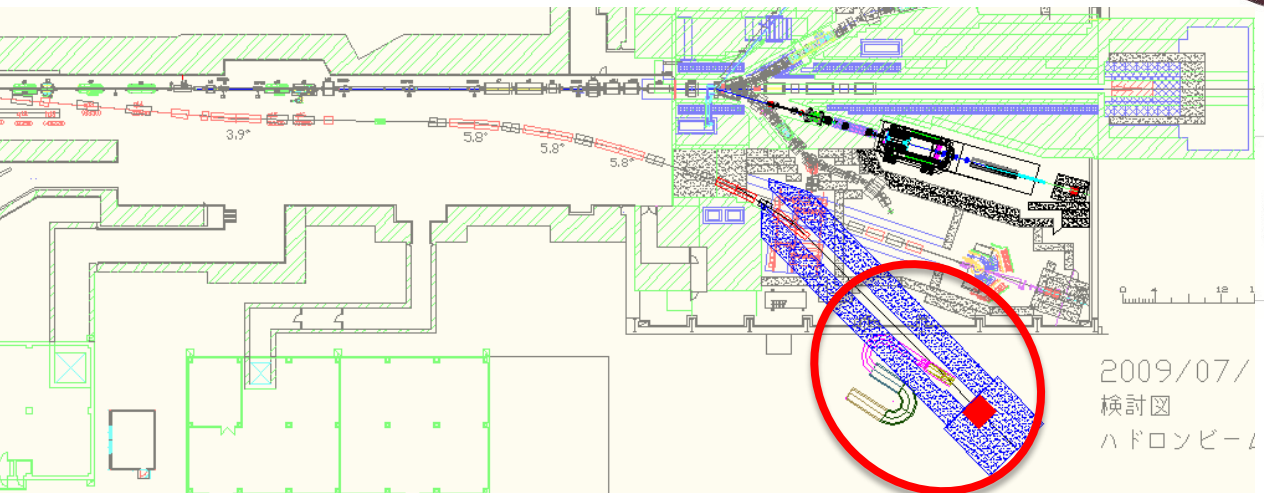


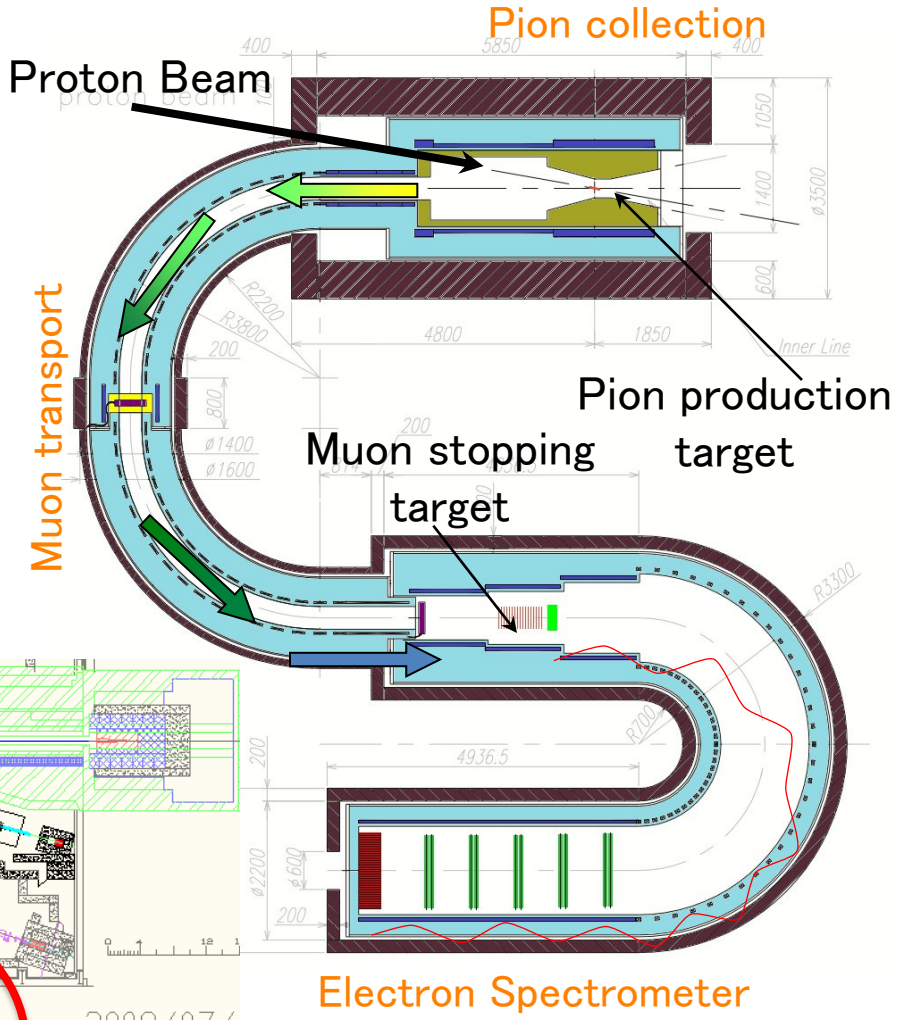
SUSY LFV loop

COMET μ-e conv. search

Phase-I phys run in 2017
Full COMET run in 2021-2022

- Search for cLFV mu-e conv.
  - **10^{-16}** sensitivity (Target S.E.S. 2.6×10^{-17})
  - Improve **O(10^4)** than present upper bound such as SINDRUM-II BR[$\mu^- + Au \rightarrow e^- + Au$] < 7×10^{-13}
- Signature: 105MeV monochromatic electron
- Beam requirement
  - 8GeV bunched slow extraction
  - 1.6×10^{21} pot needed to reach goal
  - 7 uA (56kW) x 4 SN year (4×10^7sec)
  - Extinction <10^{-9}

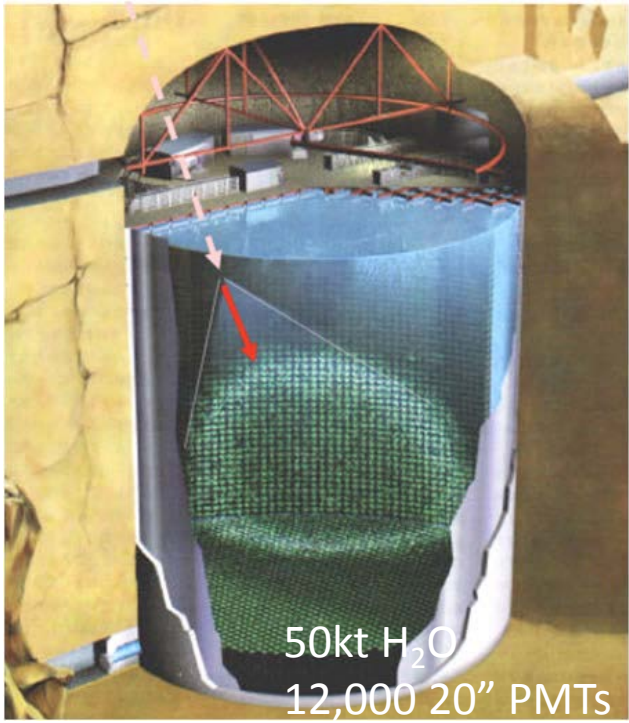




Super-Kamiokande

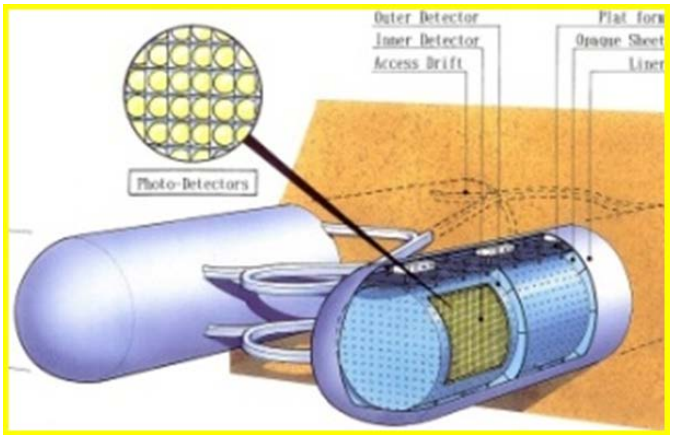
- SK have obtained many important results
  - Discovery of ν oscillation: atmospheric (1998), solar(2001 w/SNO), K2K (2004)
  - Discovery of $\nu_\mu \rightarrow \nu_e$(2011, T2K)
- Remaining tasks
  - Determine Mass hierachy, CP Violation
    - T2K and Hyper-Kamiokande
  - Supernova
    - 8,000 neutrino events from a SN at 10 kpc
  - Supernova Relic Neutrinos search (with Gd)

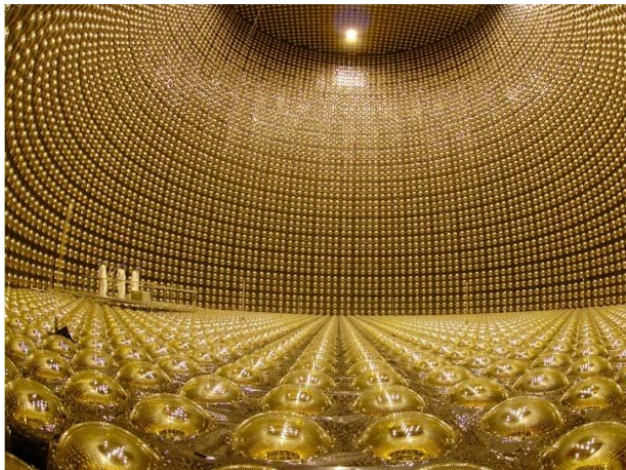
    $\rightarrow$ ~33 SRN signals for E =10~30 MeV (> 4σ)
    - Will start in a few years
  - Solar
    - Observe 'upturn' (to confirm oscillation or exotics?)



SuperKamiokande
$\rightarrow$HyperKamiokande

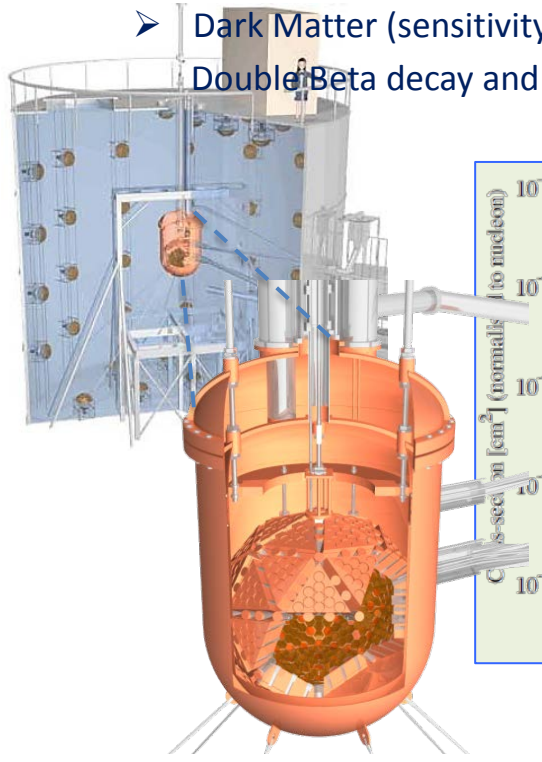
1Mt H_2O
99,000 20" PMTs

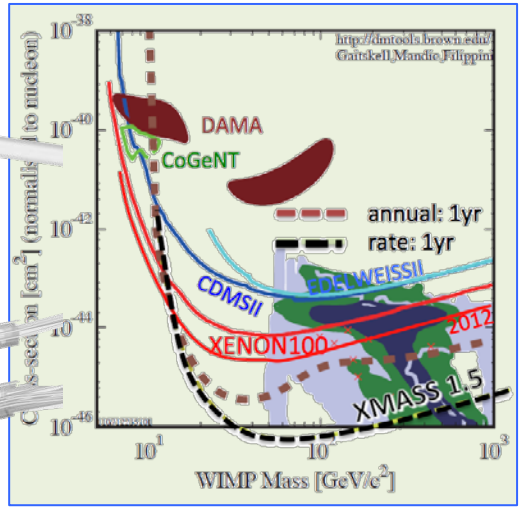




XMASS

- Phase-1: 100kg liq. Xe for dark matter search → now running
- XMASS1.5 : upgrade to 5t for better sensitivity $\sigma_{SI} < 10^{-46}$ cm^2 (at m_χ~100 GeV)
  - To be launched in 2015
- Final Goal: 10t fiducial mass
  - Dark Matter (sensitivity $\sigma_{SI} < 10^{-47}$ cm^2), Double Beta decay and pp-^{7}Be solar neutrinos

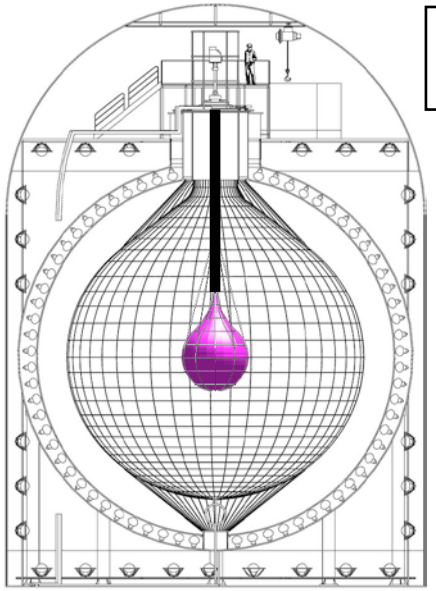




KamLAND-Zen

Zero Neutrino double beta decay search

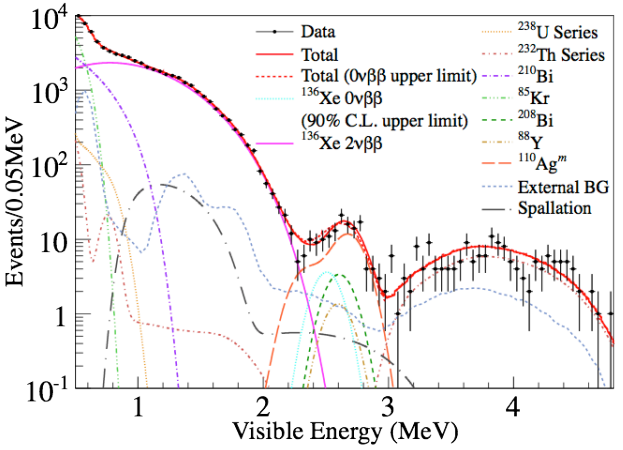
1st run with ~320kg
90% enriched ^{136}Xe



Planned improvement (2013)
~40mV sensitivity with 700kg Xe

Proposed upgrade (2016~)
~20mV sensitivity with winstone cone, higher yield LS and 1000kg Xe

Results from initial 38.5kg-yr data



$\langle m_{\beta\beta} \rangle$
<0.26~0.54 eV
@90% C.L.

Future Planning for HEP in Japan

High Energy Physics Committee (HEPC) in Japan Association of High Energy Physicists (JAHEP)

- The Subcommittee on future projects was formed under HEPC.
- The final report of the Subcommittee on Future Projects of High Energy Physics was published in February 2012.

http://www.jahep.org/office/doc/201202_hecsubc_report.

Update of KEK Roadmap is underway

- A bottom-up process: KEK is an Inter-University Research Institute Corporation
- Based on inputs from relevant science communities: HEP, Nuclear Physics, Synchrotron radiation research, Neutron science, Muon science
- Interim report is available at

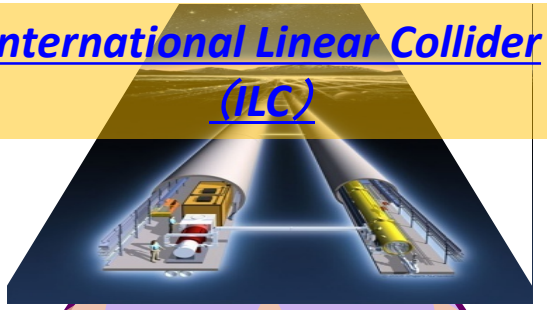
http://kds.kek.jp/conferenceDisplay.py?confId=10697 (in Japanese)

- A new roadmap "KEK Roadmap 2013" is scheduled be published in March 2013

Quest for Birth-Evolution of Universe

International Linear Collider (ILC)

Quest for Unifying Matter and Force



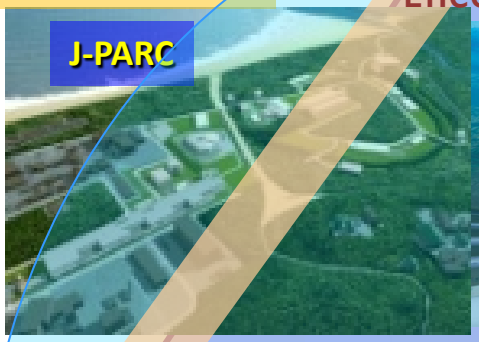
Lepton CP Asymmetry

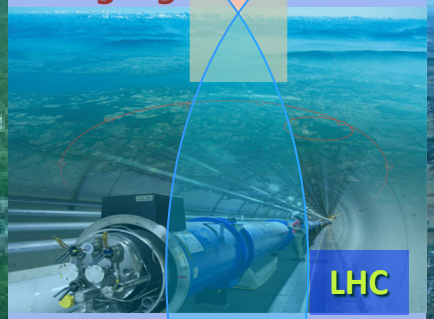
Power-Upgrade

Scientific Activities
Technology Innovation
Encouraging Human Resources

Beyond Standard Physics

Super-KEKB





Quark CP Asymmetry

Quest for 6 Quarks

Lepton

Quark

[Origin of Matter]

Quest for Neutrinos

[Origin of Force]

Higgs Particle [Origin of Mass]

Recommendations in the subcommittee report

February 11, 2012

The committee makes the following recommendations concerning large-scale projects, which comprise the core of future high energy physics research in Japan.

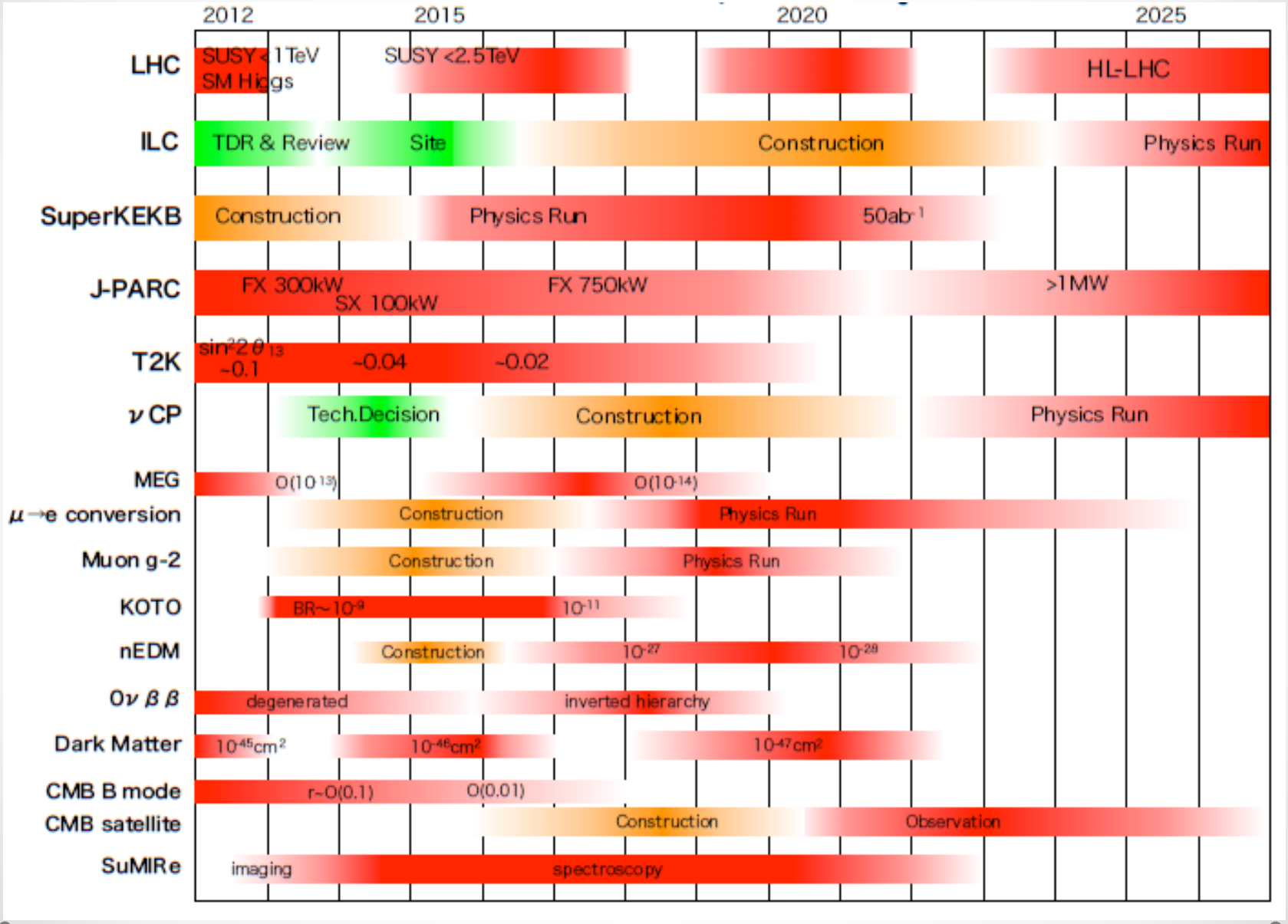
- **Should a new particle such as a Higgs boson with a mass below approximately 1 TeV be confirmed at LHC, Japan should take the leadership role in an early realization of an e^+e^- linear collider.** In particular, if the particle is light, experiments at low collision energy should be started at the earliest possible time. In parallel, continuous studies on new physics should be pursued for both LHC and the upgraded LHC version. Should the energy scale of new particles/physics be higher, accelerator R&D should be strengthened in order to realize the necessary collision energy.

- **Should the neutrino mixing angle θ_{13} be confirmed as large, Japan should aim to realize a large-scale neutrino detector through international cooperation, accompanied by the necessary reinforcement of accelerator intensity, so allowing studies on CP symmetry through neutrino oscillations.** This new large-scale neutrino detector should have sufficient sensitivity to allow the search for proton decays, which would be direct evidence of Grand Unified Theories.

It is expected that the Committee on Future Projects, which includes the High Energy Physics Committee members as its core, should be able to swiftly and flexibly update the strategies for these key, large-scale projects according to newly obtained knowledge from LHC and other sources.

It is important to complete and start the SuperKEKB including the detector, as scheduled. Some of the medium/small scale projects currently under consideration have the implicit potential to develop into important research fields in the future, such as neutrino physics and as such, should be promoted in parallel to pursue new physics in various directions. Flavour physics experiments such as muon experiments at J-PARC, searches for dark matter and neutrinoless double beta decays or observations of CMB B-mode polarization and dark energy are considered as projects that have such potential.

Time line of particle physics program in Japan



ILC Plan in Japan

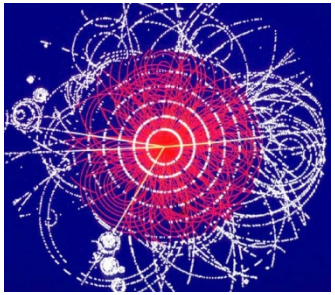
(After the discovery of a Higgs-like particle)

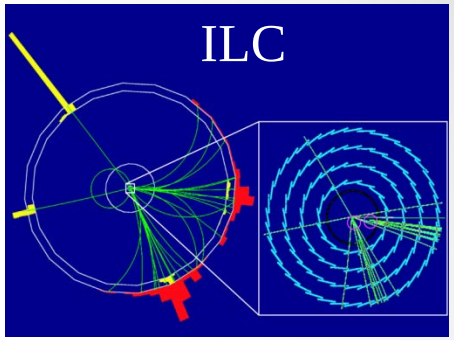
- Japanese HEP community proposes to host ILC based on the "staging scenario" to the Japanese Government.
  - ILC starts as a 250GeV Higgs factory, and will evolve to a 500GeV machine.
  - Technical extendability to 1TeV is to be preserved.
- It is assumed that one half of the cost of the 500GeV machine is to be covered by Japanese Government. However, the share has to be referred to inter-governmental negotiation.

ILC Physics

- LHC discovery of Higgs-like particle :
  - Beginning of new era of particle physics
    - Is it the Standard Model Higgs?
    - Where is the dark matter?
    - Is there really new physics at Terascale?
- ILC Higgs
  - Generate ~10K Higgs (can be tagged!)
    - 5 σ sensitivity in ~ 1 day (LHC : ~1 year)
  - Higgs Brs to a few % (LHC : a few 10s %)
    - e.g. H → cc (LHC : cannot)
  - Γ_{tot} to 5% (challenging at LHC)
  - CP to 3~4% (mix coeff)
- ILC top
  - m_t(msbar) to 100 MeV (LHC: ~ 1 GeV)
  - Anomalous ttZ, tbW, ttg coupl (LHC: hint of ttg only)
- ILC new physics
  - Composite Higgs scale to 45 TeV (LHC: ~7 TeV)
  - Anomalous WWV coupl (x10 better than LHC)

LHC



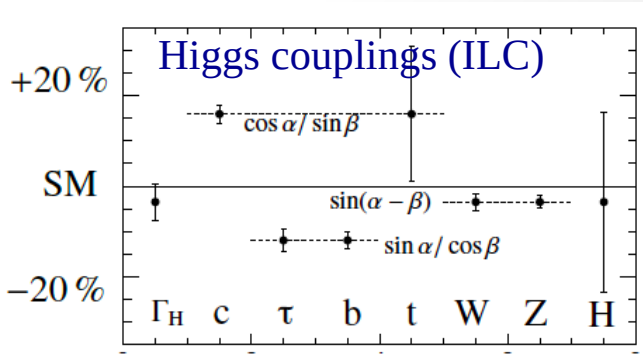


ILC: Simple and clean initial&final states

Specify Initial-state 4-momentum

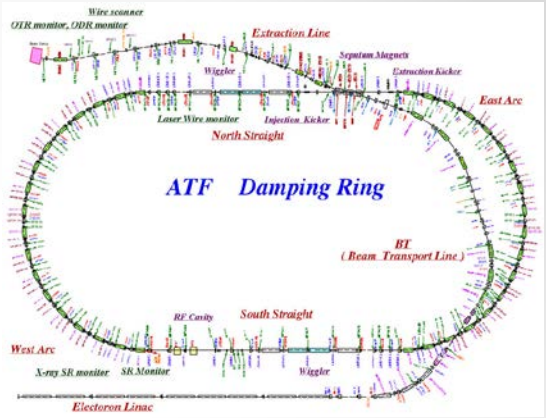
& beam polarization : control intermediate state

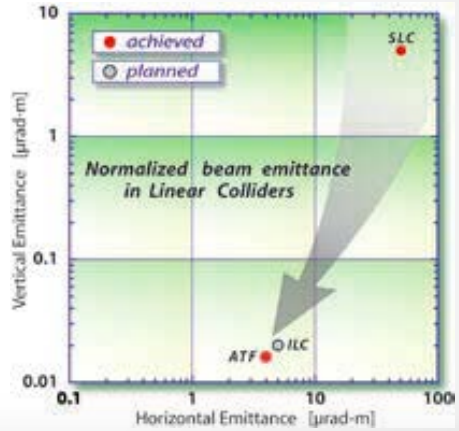
(e.g. e_R turns off $W^{\pm}$&A^0)



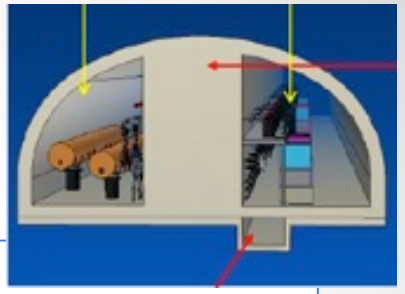
ILC Accelerator R&D at KEK

- Ultra-small beam
  - Low emittance : KEK ATF (Accelerator Test Facility)
    - Achieved the ILC goal.
  - Small vertical beam size : KEK ATF2
    - Goal = 37 nm, 160 nm achieved
      - Limit is in measurement. No basic problem seen.
  - Stabilize the beam at nm scale: KEK ATF2
    - Feedback system successful (FONT)
- Main acceleration
  - Accelerating cavity
    - Spec: 31.5 MV/m ±(<20%)
    - 80% yield achieved (90% goal is in sight)
  - Cryomodule assembly
    - Combine cavities from all over the world
      - KEK S1-global successful
- ILC technology is now ~ready

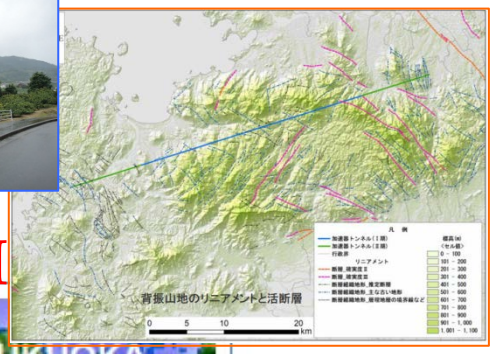




Japanese mountainous locations

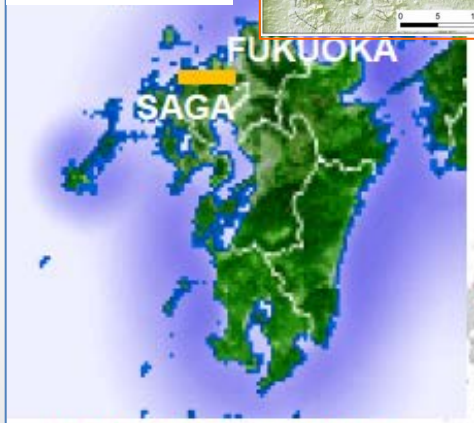


- Japanese Mountainous Sites -



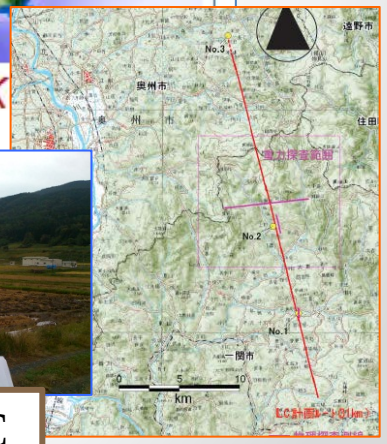
SEFURI

Site-A KITAKAMI



Tokyo

TOHOK

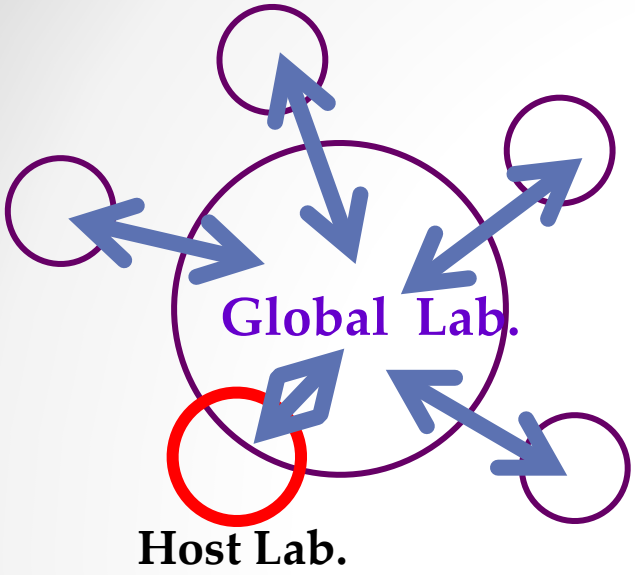


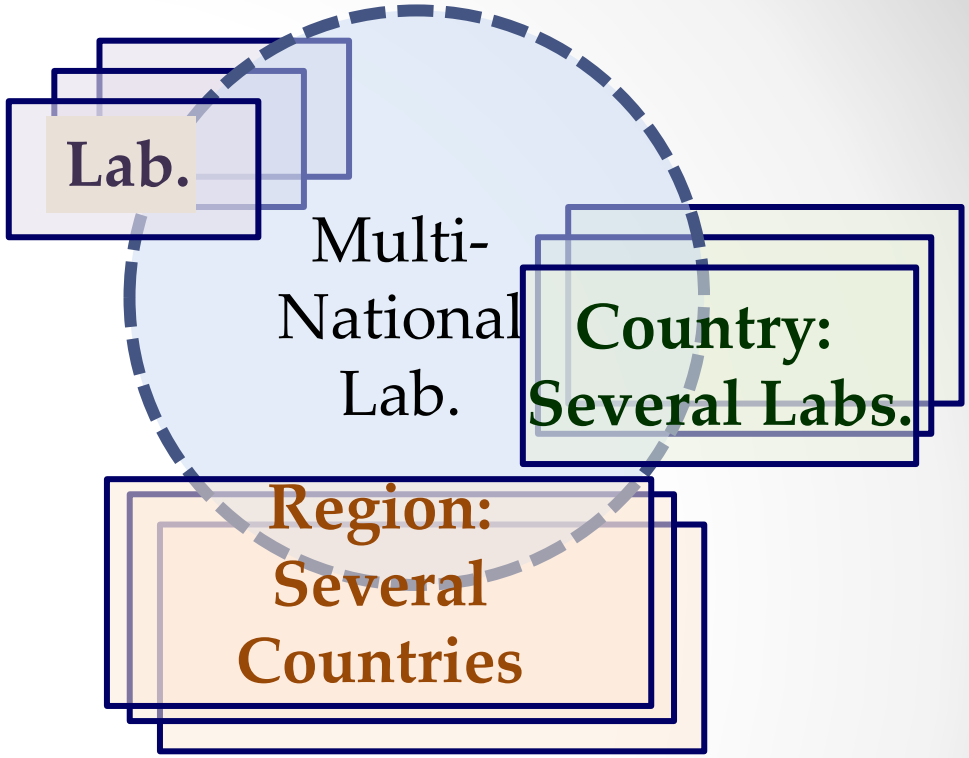
KYUSHU district

- GDE-CFS group visited two candidates sites, Oct. 14 and 15, 2011

Japanese government's third supplementary budget in 2011: 5 oku-yen to ILC

Possibility 2 : Multi-National Lab.





◆ **Brief Concept:**

※ World HEP-labs, countries and regions which wish to participate, set up their branch within Multi-national-Lab. These participating units are called a member-unit.

※ The member-units contribute in sharing the human and financial resources with in-kind and common fund issues.

※ This Multi-national-Lab is virtually built first in ICFA or a representative unit, and then, inside the host laboratory after the host-site selection.

Summary

- Current HEP projects in Japan

  Very active on-going programs

  SuperKEKB/Belle II

  T2K

  Kaon and Muon rare decay experiments at J-PARC

  SuperKamiokande, XMASS, KamLand-Zen
- Japanese HEP community recently published its report on future projects
- Japanese HEP community strongly hopes to host ILC, and making all the possible efforts: intensive R&D on machine and detector, site investigation, organizational issues and actions to get understandings of general public and government.