INTER-UNIVERSITY RESEARCH INSTITUTE CORPORATION
HIGH ENERGY ACCELERATOR RESEARCH ORGANIZATION

KEK future programme for particle physics

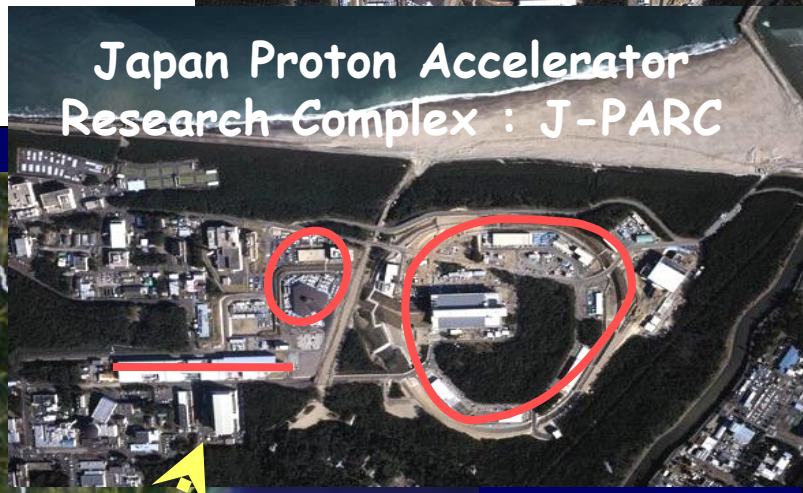
Yasuhiro Okada, Executive Director, KEK

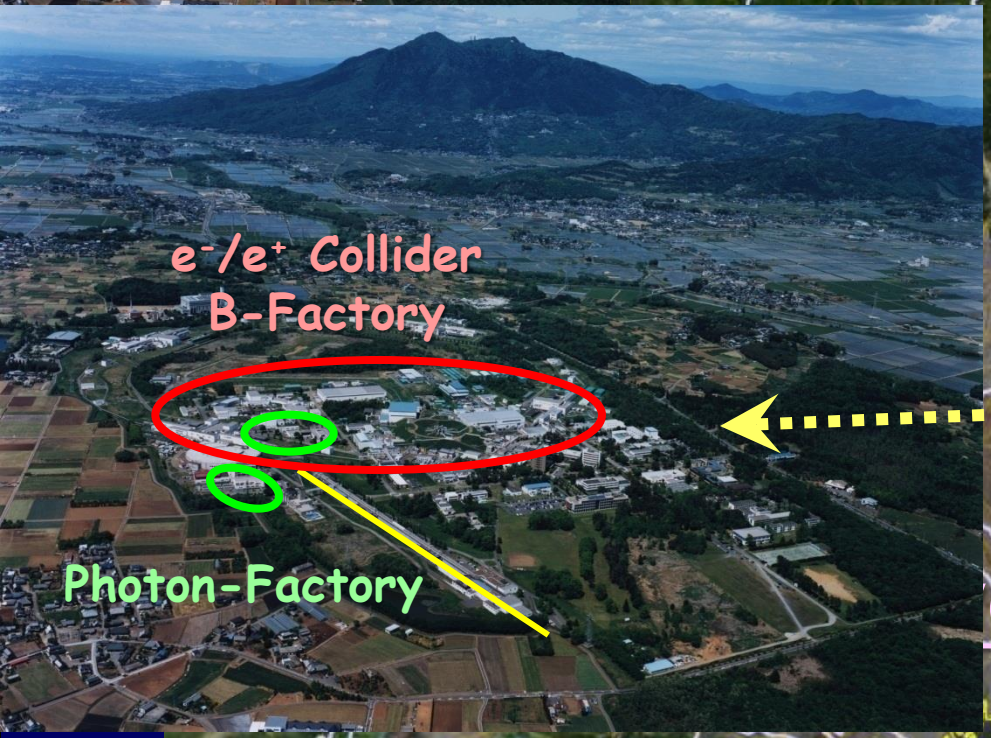
4th Joint HiLumi LHC-LARP Annual Meeting 2014

November 17, 2014, KEK Japan

KEK : Research Center for High Energy Accelerator Science

Japan Proton Accelerator Research Complex : J-PARC





e^-/e^+ Collider
B-Factory

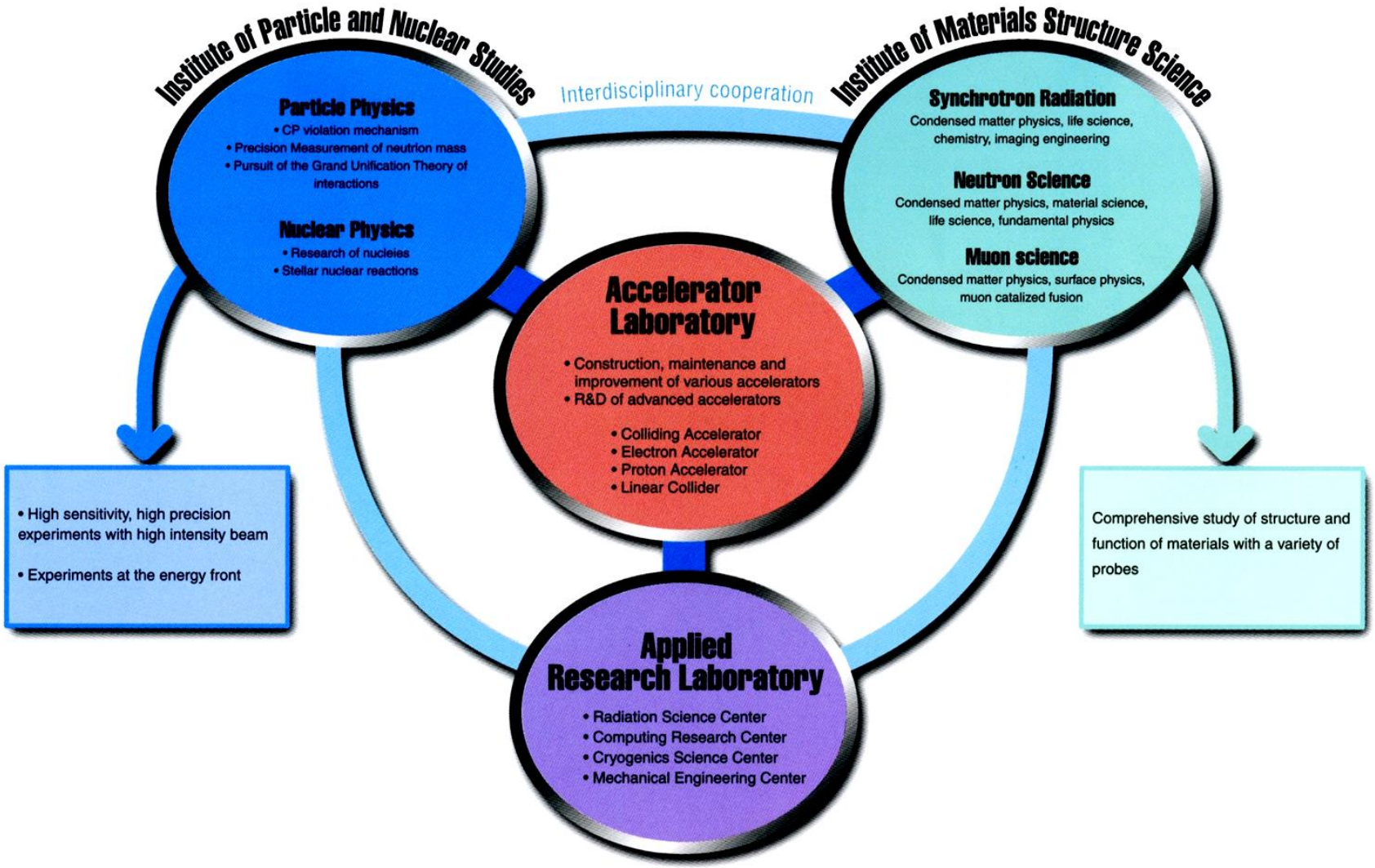
Photon-Factory

Tokai

Tsukuba

International Collaboration : LHC……

Structure of KEK: Two institutes and two laboratories



J-PARC: Joint project between KEK and Japan Atomic Energy Agency (JAEA)

Inter-University Research Institute Organization

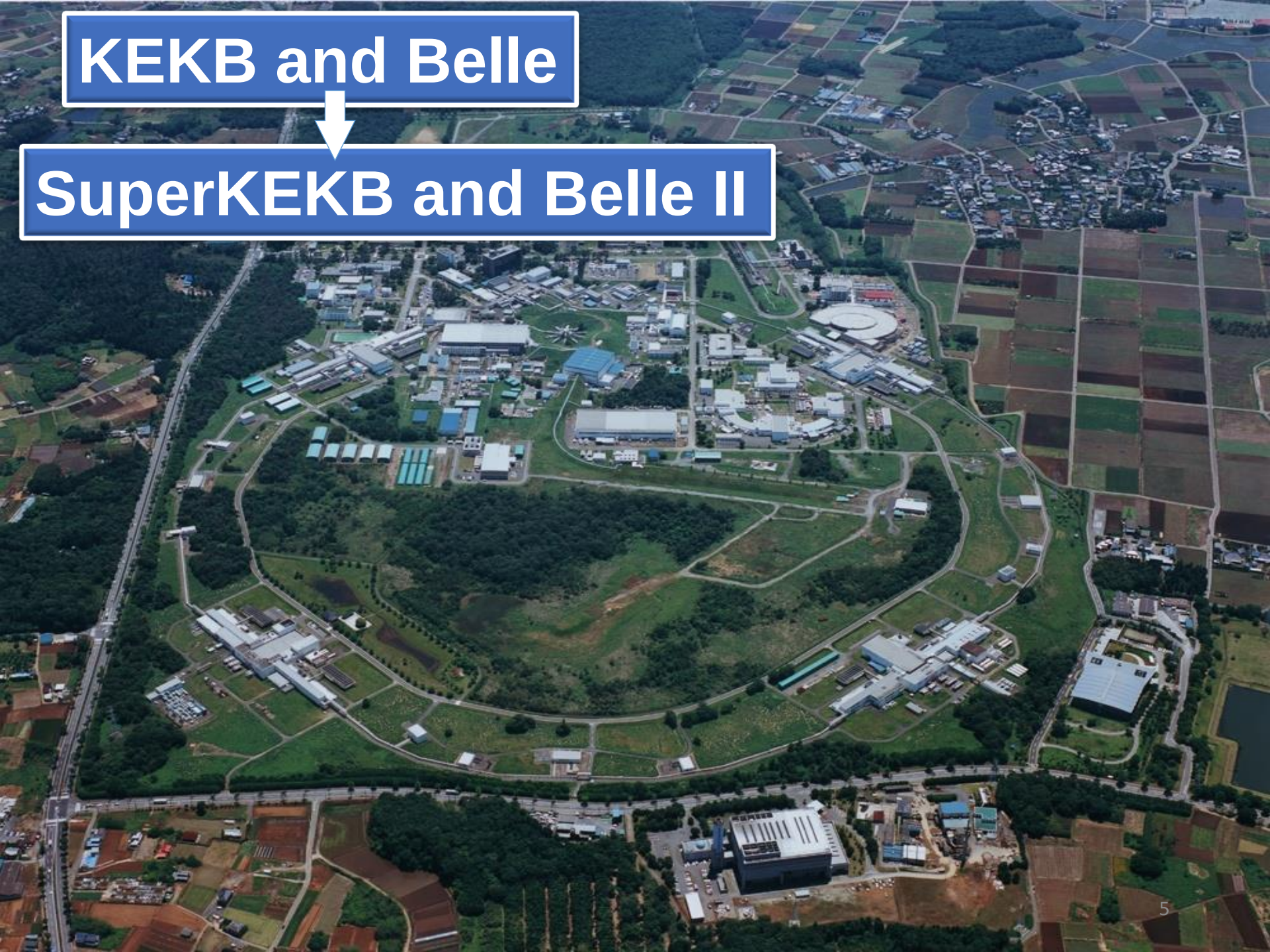
- KEK is Inter-University Research Institute Organization, first established in 1971 as National Laboratory for High Energy Physics
- An International Center of Accelerator Science
- Cover wide range of scientific fields
- KEK established the first roadmap for the research strategy in 2008 and updated it in 2013. KEK Roadmap 2013 is available at the KEK homepage.

KEK Roadmap 2013

Strategy for Next Five Years (2014-2018)

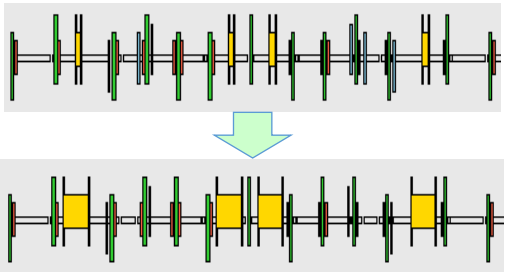
- J-PARC
- SuperKEKB/Belle II
- LHC/ATLAS
- ILC
- Photon Science (Synchrotron Radiation Research)
- New Development of Accelerator and Detector Technologies

http://www.kek.jp/en/About/Roadmap/

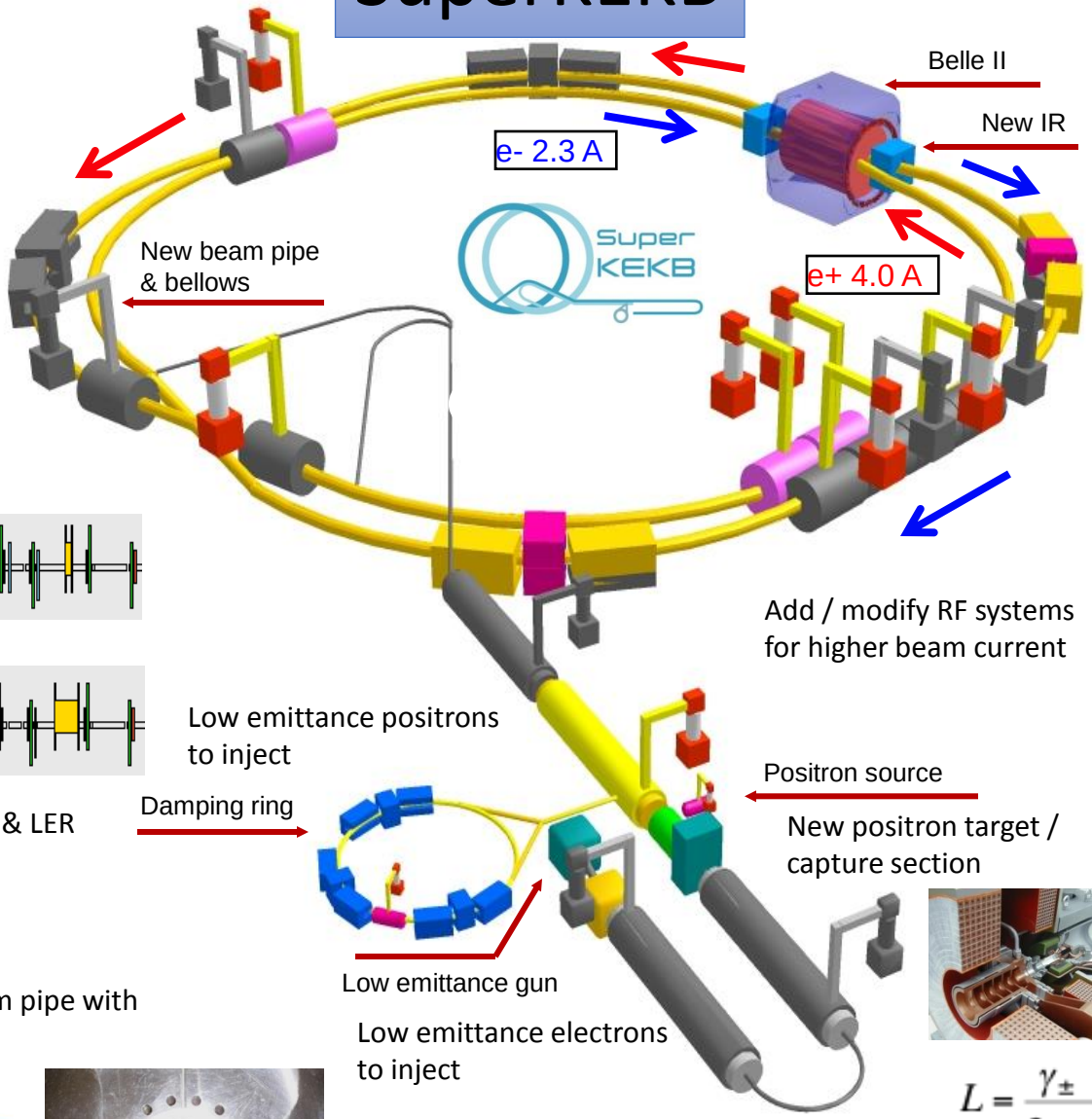

KEKB and Belle
SuperKEKB and Belle II

SuperKEKB

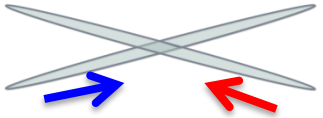
Replace short dipoles with longer ones (LER)



Redesign the lattices of HER & LER to squeeze the emittance

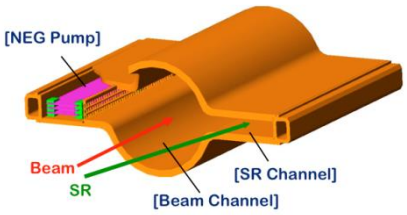


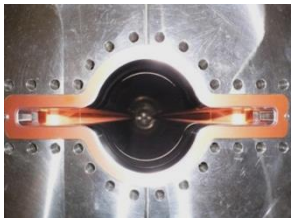
Colliding bunches



New superconducting /permanent final focusing quads near the IP

TiN-coated beam pipe with antechambers





$$L = \frac{\gamma_\pm}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\frac{I_\pm \xi_{\pm y}}{\beta_y^*}\left(\frac{R_L}{R_y}\right)$$

$L=8\cdot10^{35}\ s^{-1}cm^{-2}$

x 40 Gain in Luminosity

Belle II Detector Upgrade

K_L and muon detector:
Resistive Plate Counter (barrel outer layers)
Scintillator + WLSF + MPPC (end-caps, inner 2 barrel layers)

EM Calorimeter:
CsI(Tl), waveform sampling (barrel)
Pure CsI + waveform sampling (end-caps)

Particle Identification
Time-of-Propagation counter (barrel)
Prox. focusing Aerogel RICH (fwd)

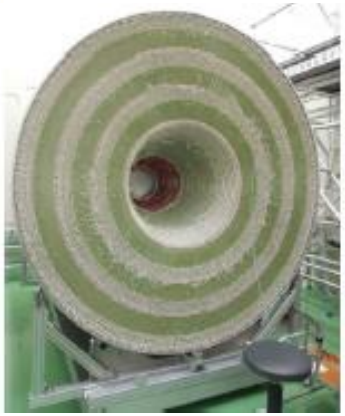
electron (7GeV)

Beryllium beam pipe
2cm diameter

Vertex Detector
2 layers DEPFET + 4 layers DSSD

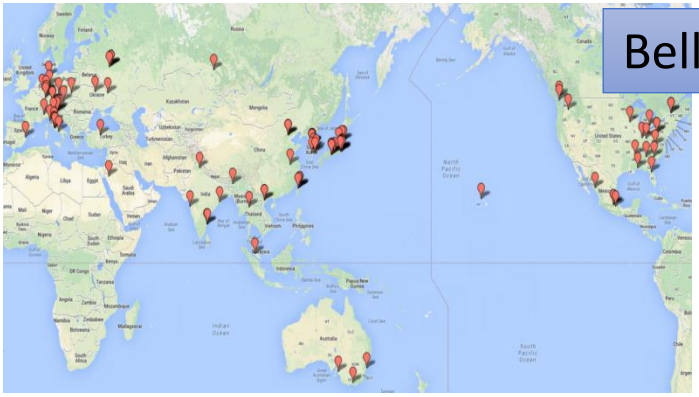
positron (4GeV)

Central Drift Chamber
He(50%):C_2H_6(50%), Small cells, long lever arm, fast electronics



Construction In Progress

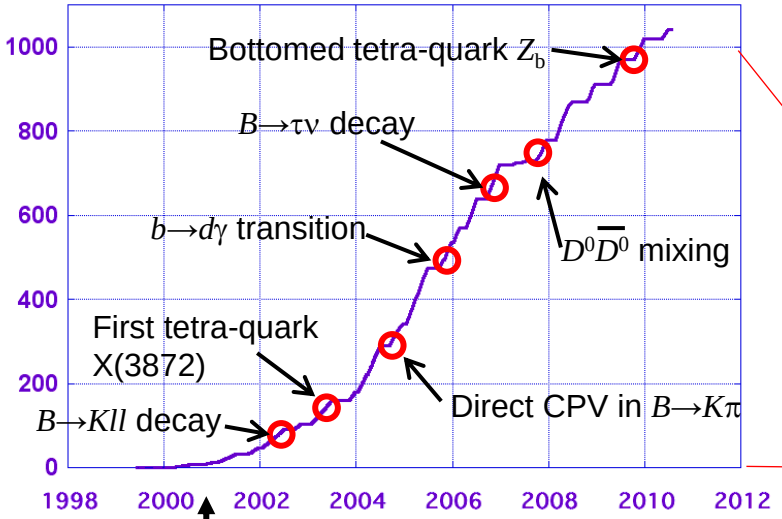
Belle II Collaboration



~600 collaborators from 97 institutions in 23 countries/regions

Belle II

fb^{-1}

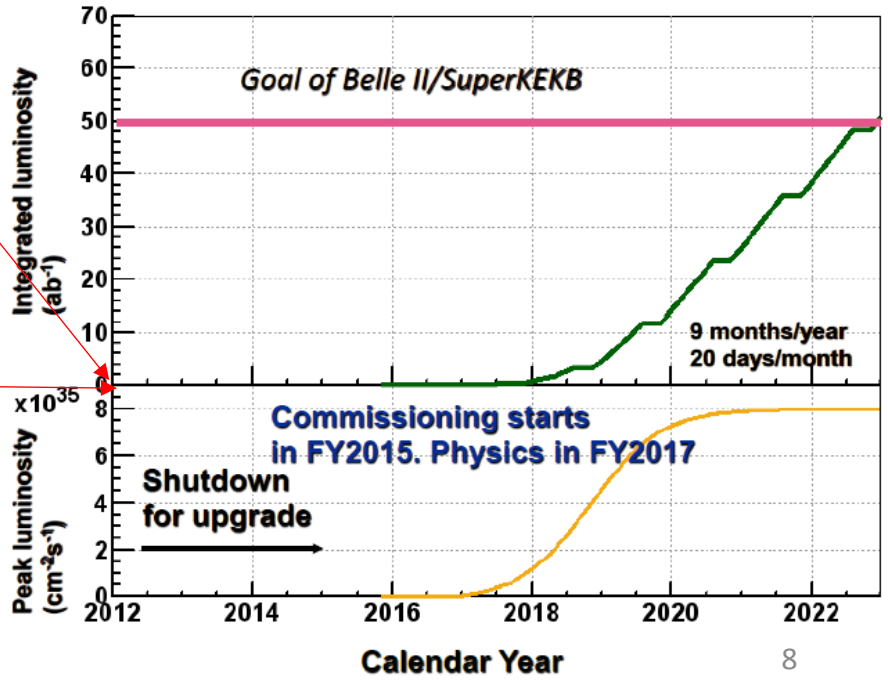


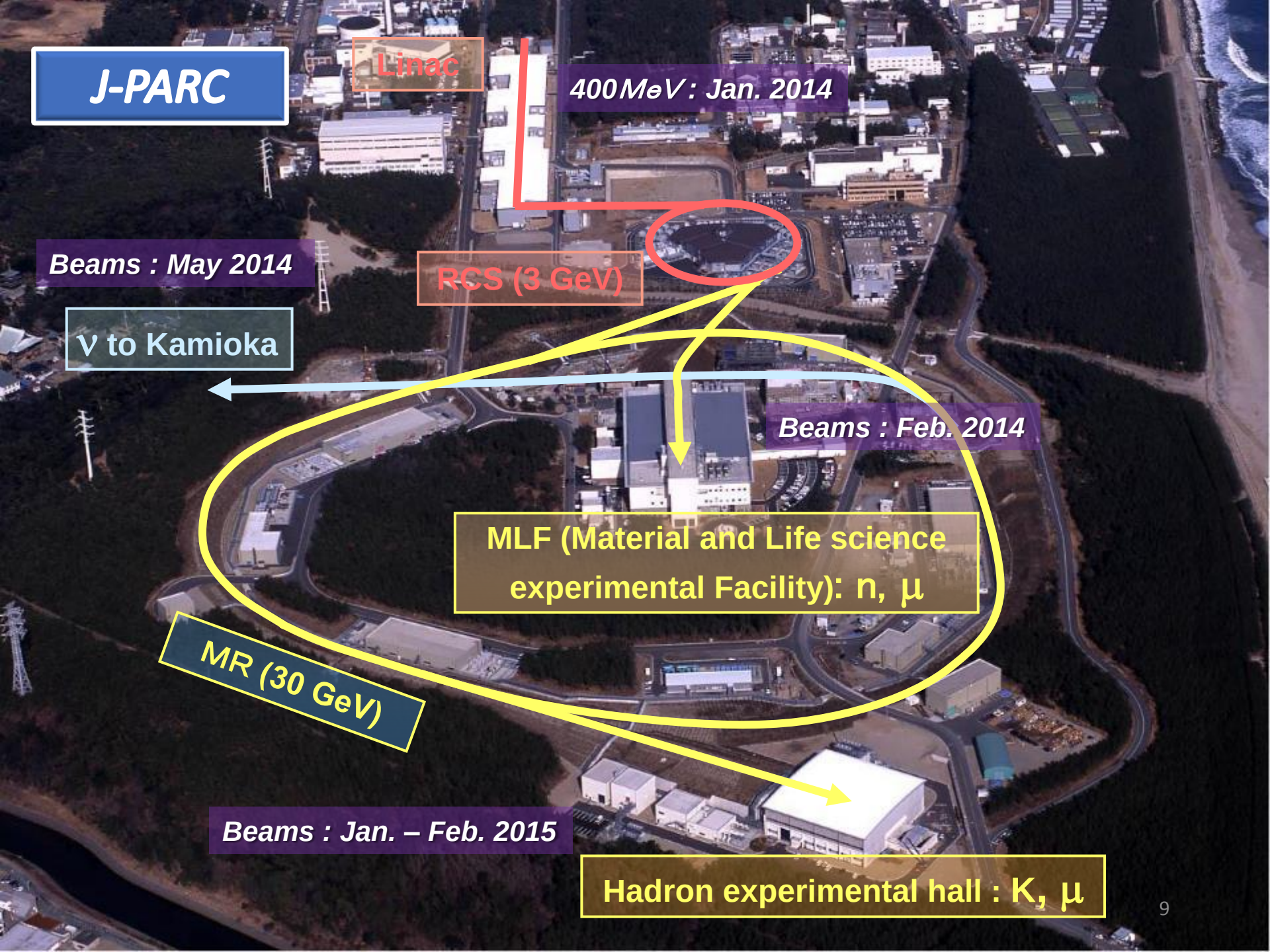
Belle

Discovery of
CP violation in B decays

ab^{-1} =1000fb^{-1}

Projected luminosity




J-PARC
Linac
400MeV : Jan. 2014
Beams : May 2014
RCS (3 GeV)
ν to Kamioka
Beams : Feb. 2014
MLF (Material and Life science experimental Facility): n, μ
MR (30 GeV)
Beams : Jan. – Feb. 2015
Hadron experimental hall : K, μ

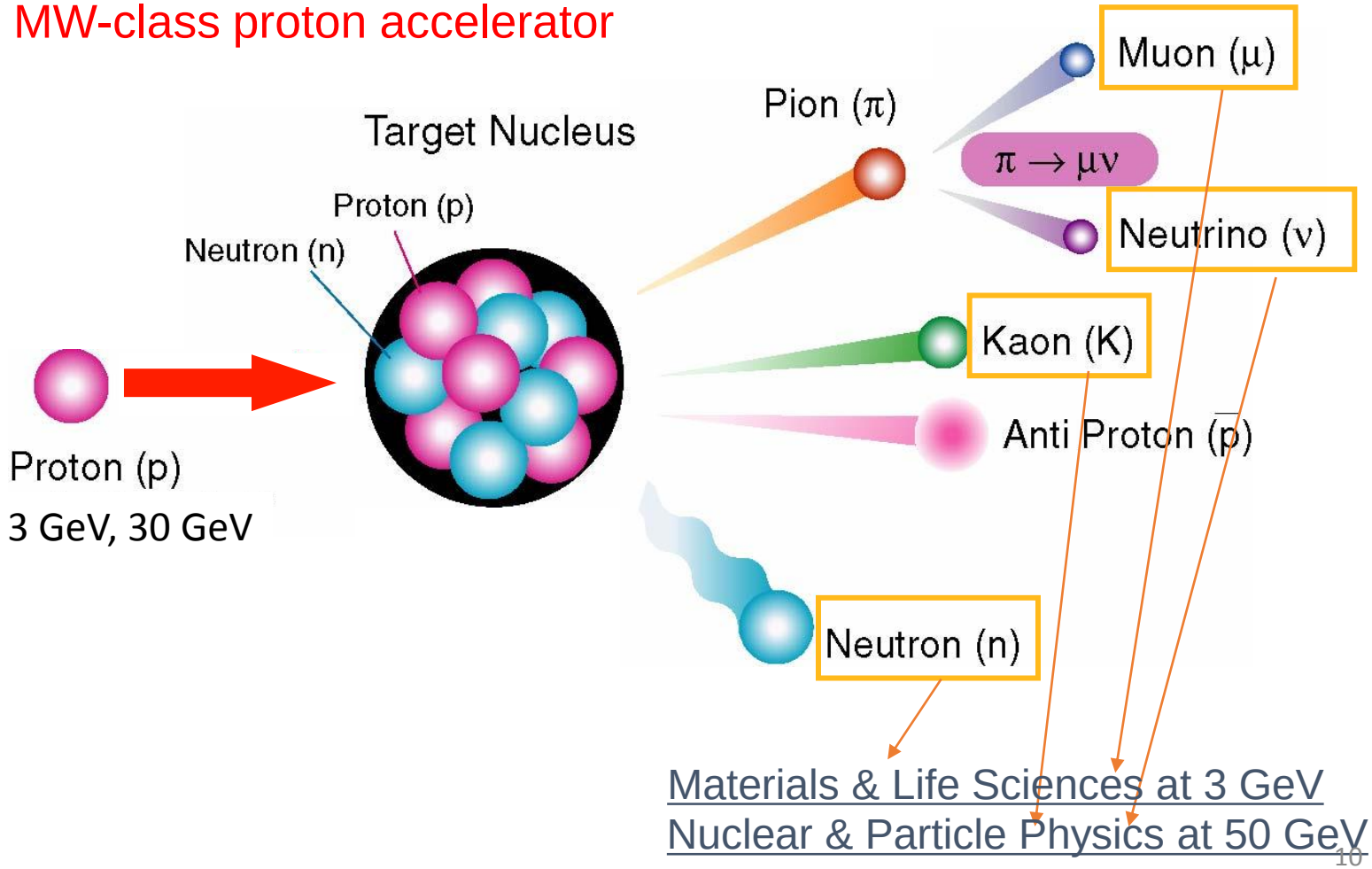
J-PARC

J-PARC = Japan Proton Accelerator Research Complex

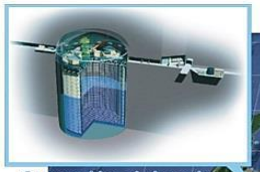
Joint Project between KEK and JAEA

Goal

→ MW-class proton accelerator

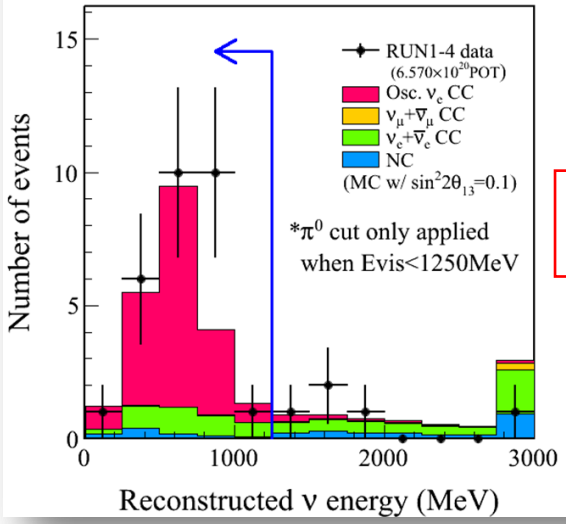


T2K: Long Baseline Neutrino Experiment



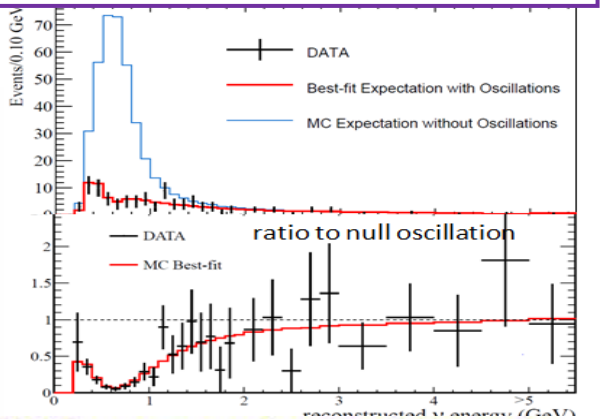
~500 members, 61 Institutes, 12 countries

- Stable operation at ~230kW achieved
- 7.39x10^{20} POT by June
  - >1.2x10^{14}ppp(1.5x10^{13}x8b) is the *world record* of extracted protons per pulse for synchrotrons
  - first anti-ν running in 2014
  - Data :6.57x10^{20}POT by 2013

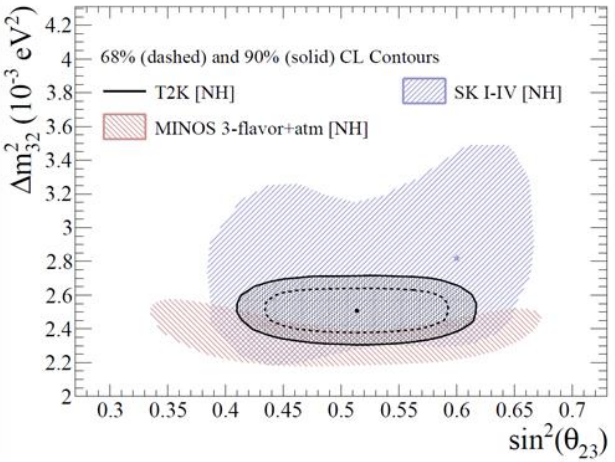


- 28 ν_e candidates events were observed while background expectation is 4.9
- Observation of ν_e appearance with 7.3σ significance
- Slightly larger than δ_{CP}=0 expectation→constraint on δ_{CP}

ν_μ disappearance measurement

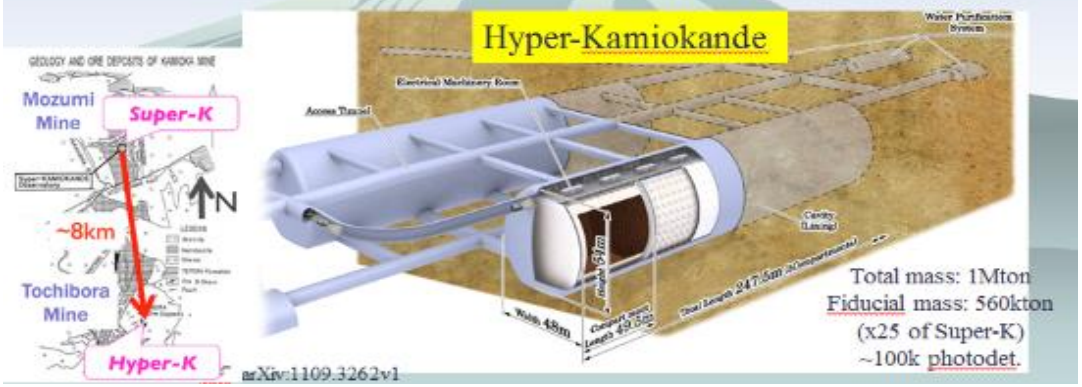


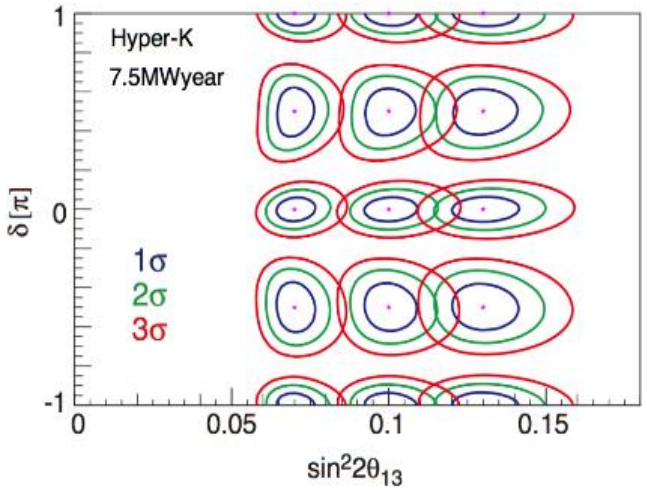
T2K favors maximal mixing of θ_{23}



The next generation LBL experiment w/ HK

- ~1MW (or higher) J-PARC MR +T2K beamline
- New huge detector: 1Mt Water Ch. Hyper-Kamiokande @ Kamioka
- Physics goals: CPV (w/ J-PARC ν beam), Mass hierarchy w/ Atm ν, proton decay, etc, find something unexpected!
- Communities support HK at high priority
  - HEP: One of two highest priority large projects (other is ILC)
  - Cosmic: endorses HK at high priority
  - HK project plan is submitted to the master plan for large scale projects in SCJ





Requirement : joint proposal of HK and J-PARC upgrade

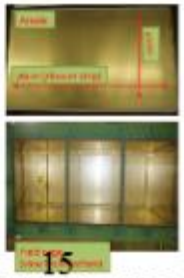
Liquid Ar TPC Activity in Japan

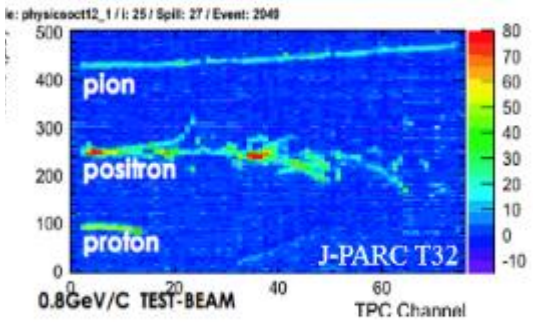
Experimental assessment of detector performance such as dE/dx measurement is performed with 250L set up

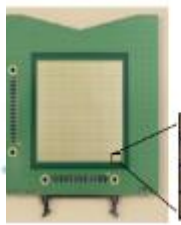
Single phase 2D charge readout plane

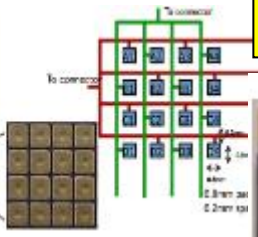
Economical low noise readout electronics with ASIC technology eventually applicable in cold environment

250L set up

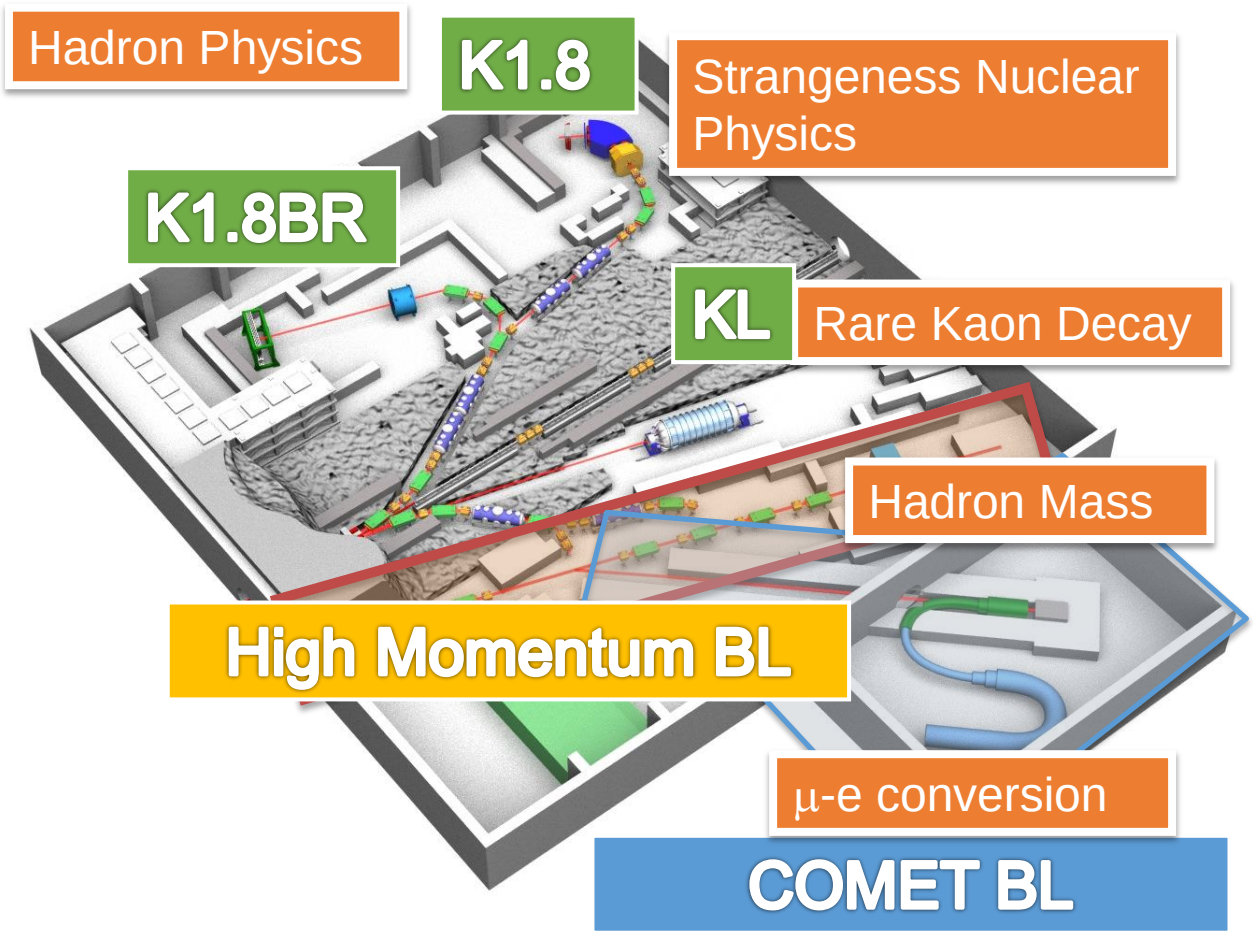

TPC for 250L







Nuclear & Particle Physics with J-PARC Hadron Beam



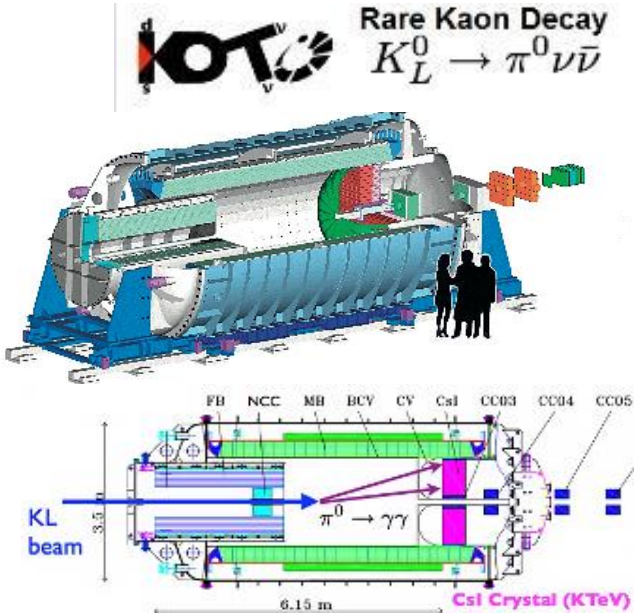
International Collaboration Experiments

KOTO
Search for CPV in KL->πνν
(Physics Run started)

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

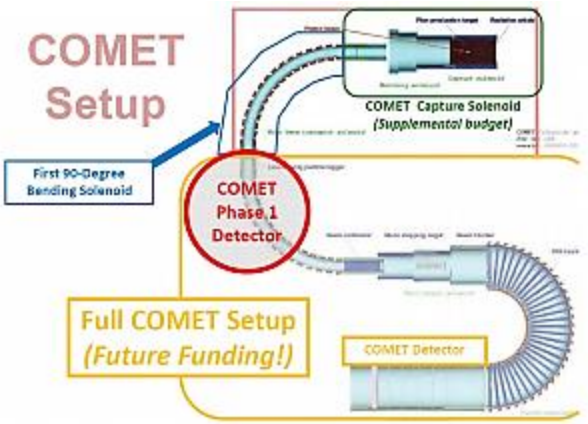
Muon g-2/EDM
(R&D phase)

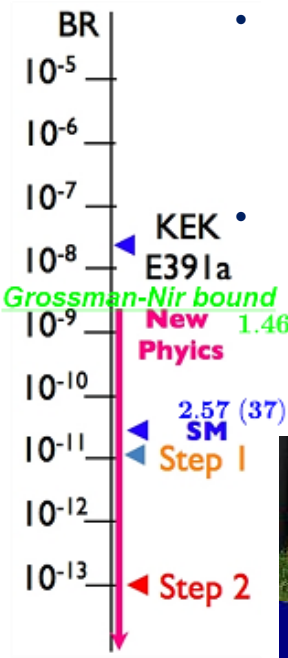
COMET
COherent Muon to Electron Transition



μ-e conversion

$$\mu^- + (A,Z) \rightarrow e^- + (A,Z)$$

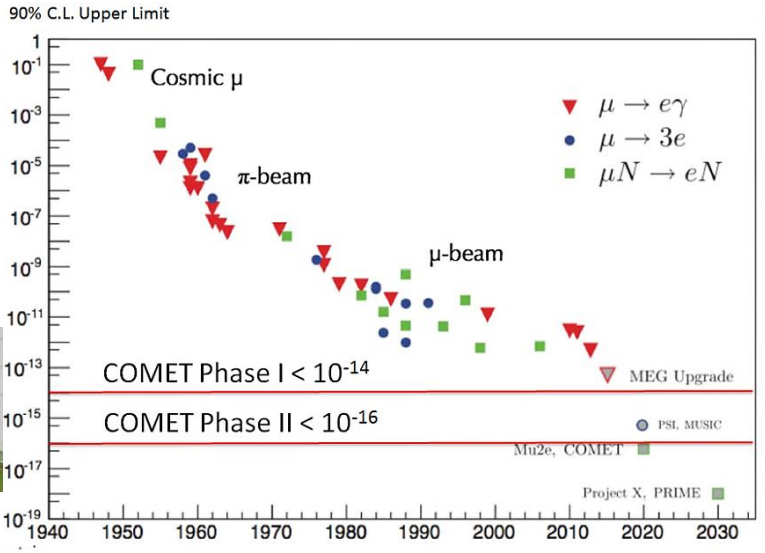




- Started running in 2013, first results (preliminary) reported at the CKM2014 workshop in September.
- Single event sensitivity
  - ≈ Standard Model by 2018 run.

160 researchers from 32 institutes

in 13 countries + 1 international institute



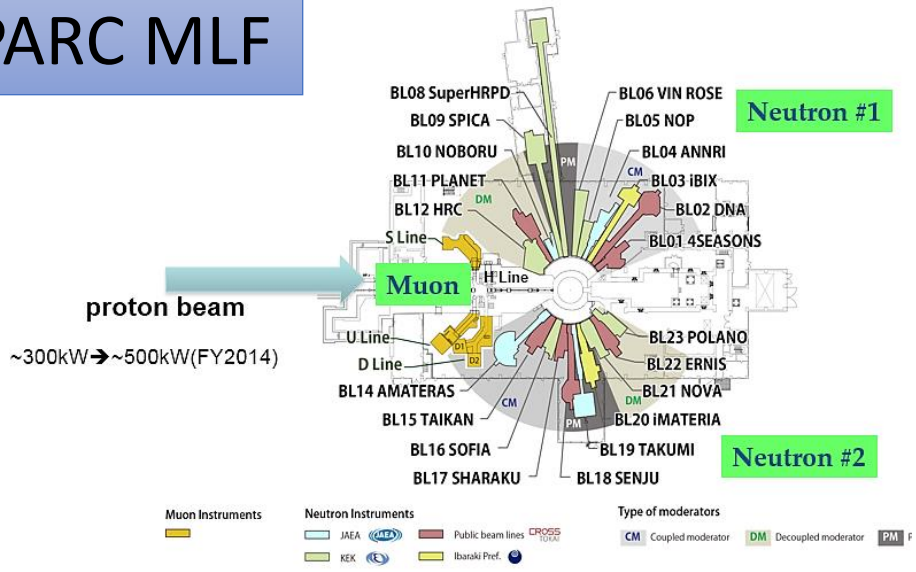
2016-2017

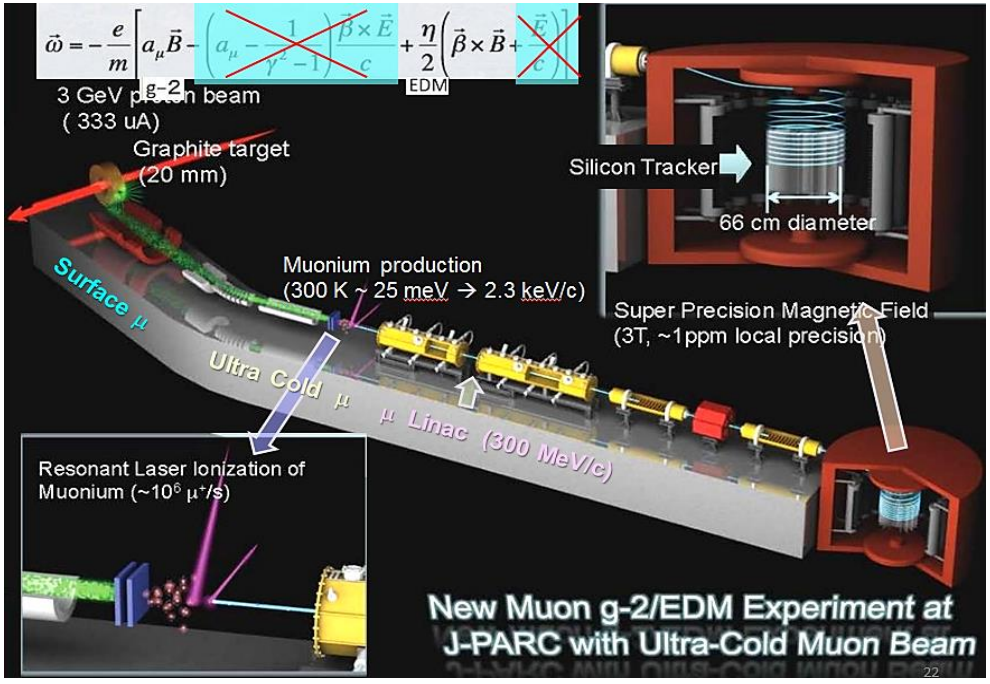
2021

Muon g-2 experiment@ J-PARC MLF

Improve Precision by 5 (0.1 ppm)

Improve Precision by 100 EDM



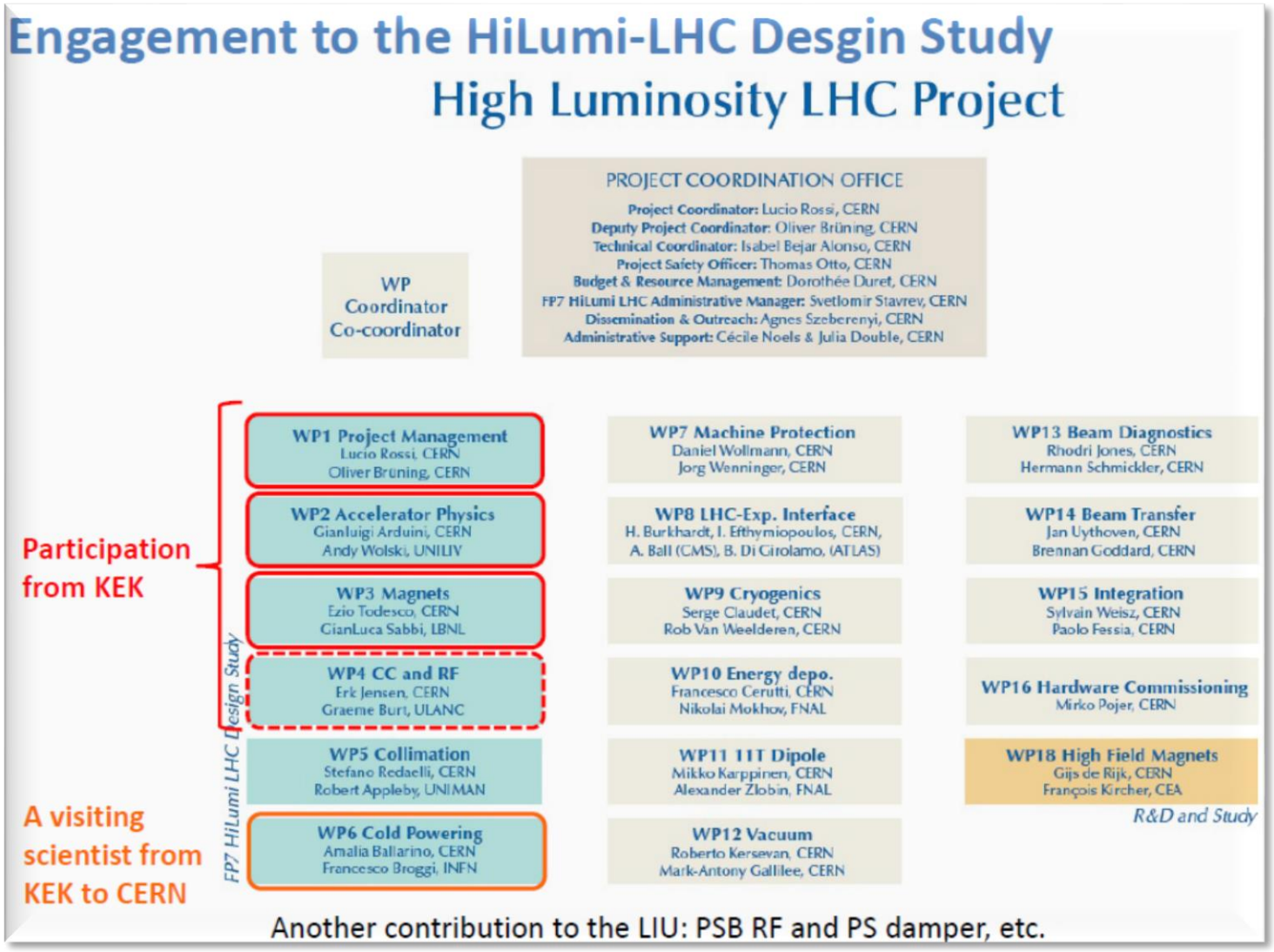


Intended Schedule

	2013	2014	2015	2016	2017	2018
Muon Sournce	R&D / Design			Construction		Experiment
Muon LINAC	R&D / Design			Construction		
Ultra-Precision Magnet	R&D / Design			Construction		
Detector	R&D / Design		Construction			

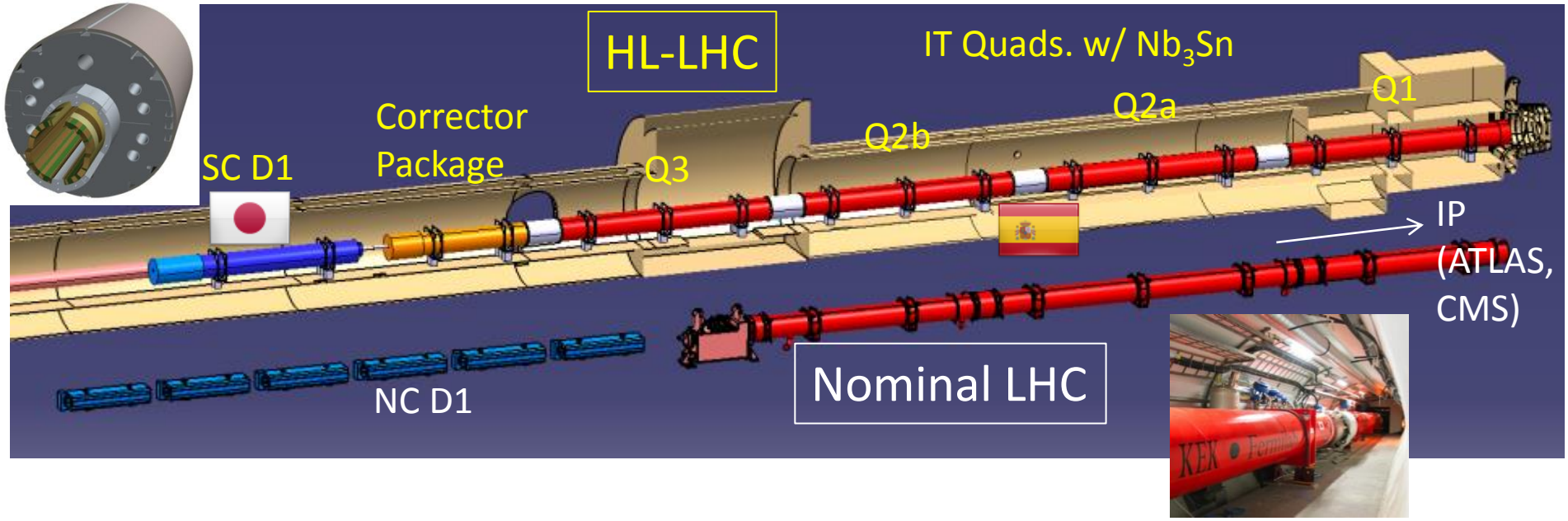
98 members from 21 institutes in 8 countries

Japanese Contribution to HL-LHC



Review on Japanese Contribution to ATLAS/LHC Upgrade was held on Nov. 21-22, 2013

New D1 in IR (ATLAS, CMS) at HL-LHC



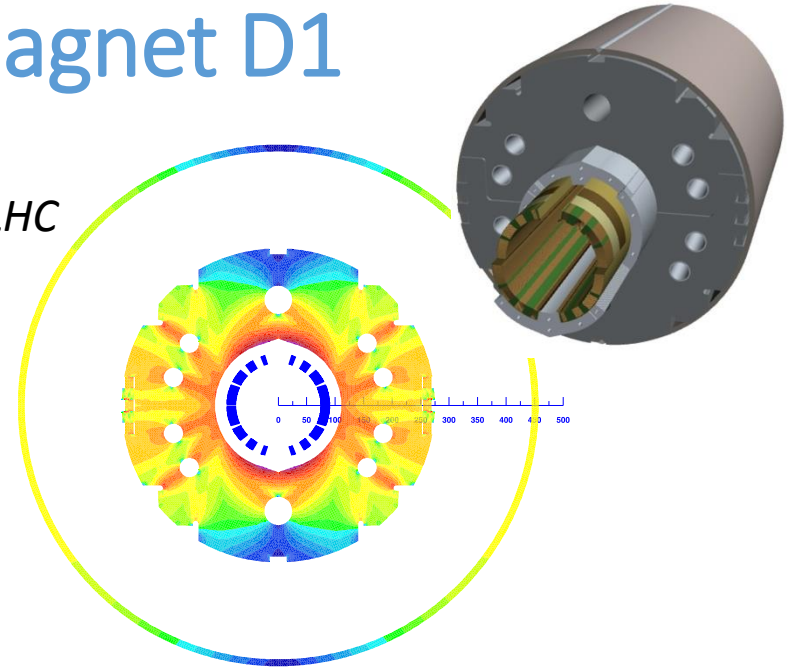
- A large aperture of 150 mm, same as new low-β quadrupoles to reduce β*
- Short distance between D1 and D2.

NEW strong beam separation SC dipole, D1, for HL-LHC

- *In-kind contribution (still plan…)*
  - *6 full-scale D1 beam separation magnets assembled in cryostats*
    - *4 for HL-LHC machine, 2 for spares.*
    - *All cold masses to be evaluated at warm and cold.*
    - *Only 1 or 2 full cryostats to be evaluated at cold.*

Development of 2m model magnet D1

- *Coil ID:* ***150 mm***
- *Integrated field:* ***35 T m*** *(26 Tm at present LHC) for HL-LHC*
  - ***5.59 T at 12 kA****, L_{coil}=6.3 m, E= 2.1 MJ*
- *T_{op}:* *1.9 K by HeII cooling*
- *Conductor:* *Nb-Ti LHC MB outer cable (by CERN)*
- *Structure:* *Collared yoke structure by keying*
- *Cold mass OD:* *550 +10 x 2 = 570 mm*
- *Cryostat OD:* *914 mm, same as MB cryostat*
- *Radiation, energy deposition:* ***25 MGy, ~2 mW/cm³***



- Activity in WP3, and development in collaboration with CERN.
- First model magnet will be fabricated and tested in 2015.

Challenges:
- Stress management
- Field quality under high saturation
- Radiation resistance, cooling capability


Coil end spacers with NEW radiation resistant GFRP


Completed test coil


Test coil winding

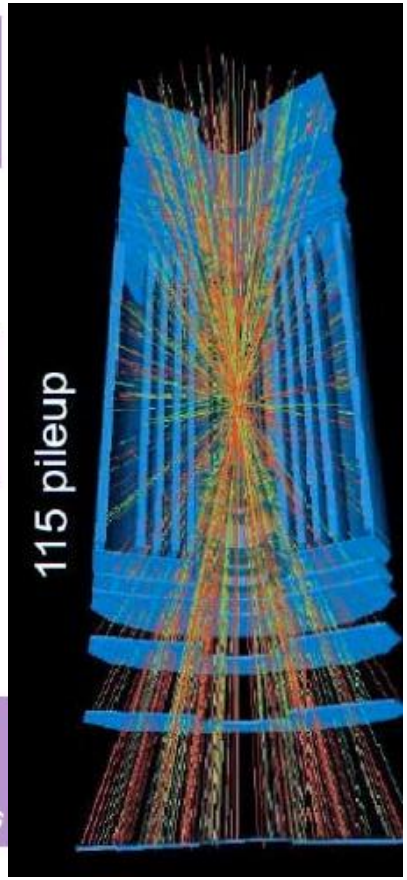
ATLAS Upgrade

L=5 ×10³⁴ ~ 100 pileups

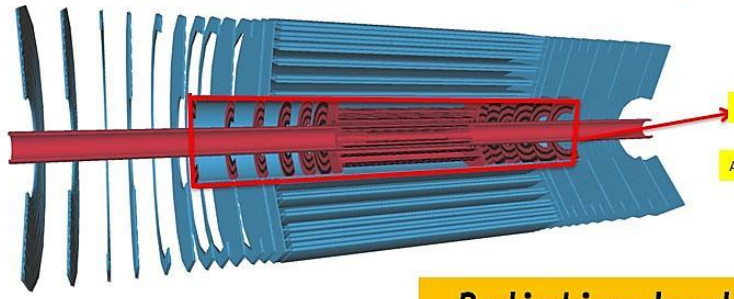
2010 O(2) pileups

2011 O(10) pileups

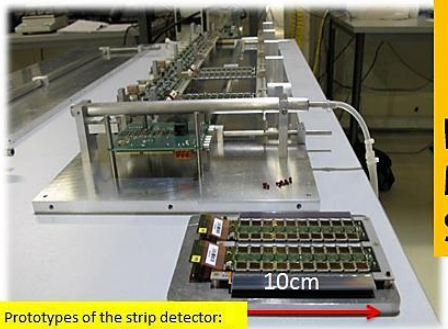
2012 O(20) pileups



ATLAS upgrade (1) Inner tracker replacement



A new inner tracker design



Prototypes of the strip detector: produced by KEK and Geneva U.

Radiation hard trackers are already in reality!

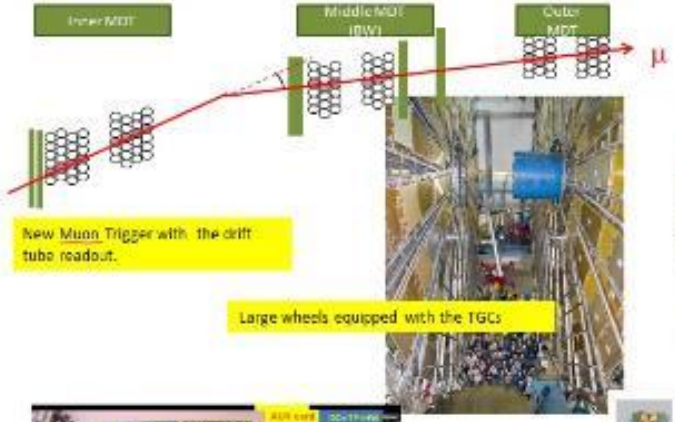
We need a huge investiment.

Pixel 8.2 m² 600 M ch.

Strip 193 m² 70 M ch.

1

ATLAS upgrade (2) Trigger upgrade

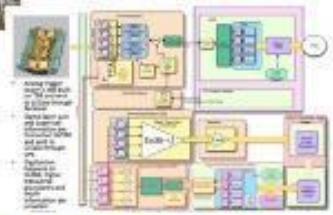


New Muon Trigger with the drift tube readout.

Large wheels equipped with the TGCs

Upgrade of the small wheel

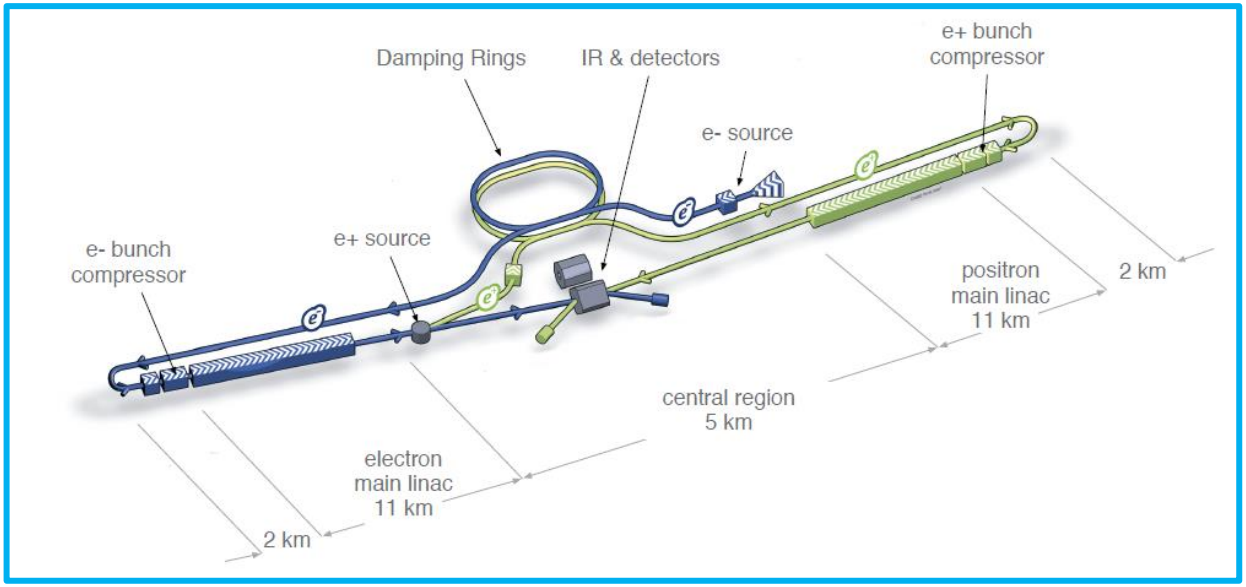
Track trigger (Waseda University)



CAL trigger upgrade (U. of Tokyo)

International Linear Collider (ILC)

- The next generation e+e- collider (500GeV, upgradable to 1TeV)
- Design work and accelerator R&D have been carried out in a global framework. The ILC TDR was completed by Global Design Effort (GDE) in 2013 and the next phase of design and R&D works has started under the leadership of Linear Collider Collaboration (LCC).
- Discovery of a Higgs particle at LHC in July 2012 set a clear physics target of the initial stage of the ILC.
- KEK set up the Planning Office for the ILC in January 2014.
- Based on the recommendations by Science Council of Japan, MEXT set up Special Committee on ILC Project in May 2014 to investigate critical issues required to judge hosting ILC or not by 2016 . Status reports from two WGs (Revisiting Scientific Merit, Evaluation of TDR & Cost Estimates) was presented at the second meeting on Nov. 14, 2014)



ILC Recent progress of KEK-ATF

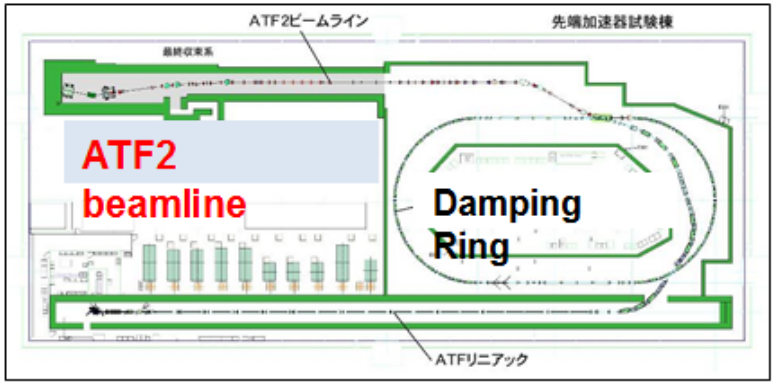
ATF2: Final focus Test beamline

Goal-1: Develop final focus system for ILC

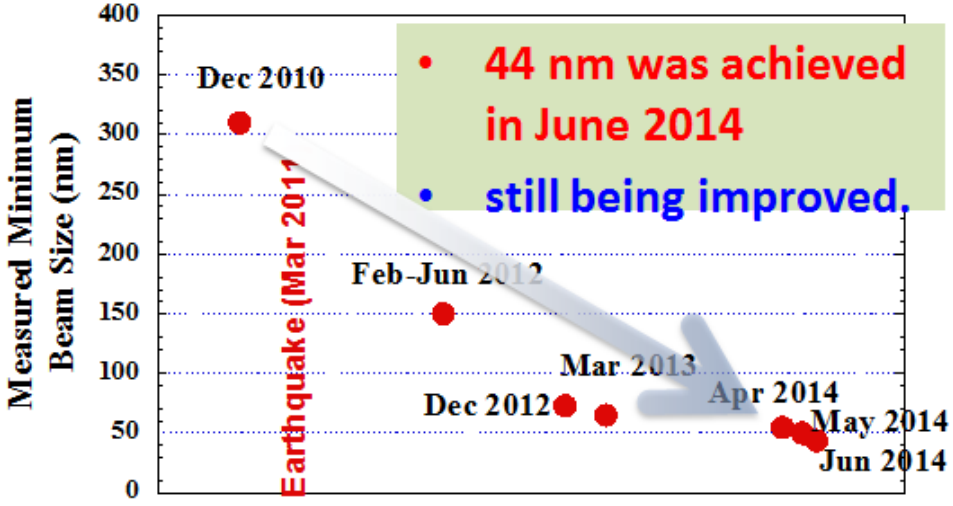
→ 37 nm vertical beam size at IP

Goal-2: Develop beam position stabilization in a few nm

→ Study of Intra-train feedback has been started.

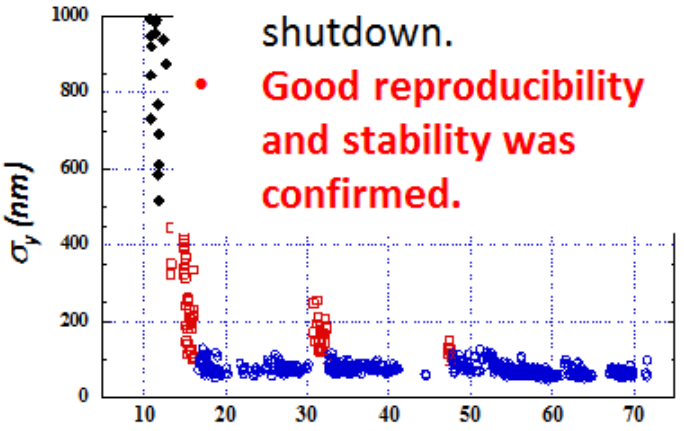


History of measured minimum beam size



Presented by K.Kubo at IPAC2014

- Small beam size (<50 nm) was recovered in a day from an accelerator shutdown.
- **Good reproducibility and stability was confirmed.**



ILC STF Accelerator under construction

CM-1 cavities: Average Gradient 36MV/m before installation

STF Accelerator parameters
Beam Energy : 418MeV
Beam Charge : 2nC/bunch, 2437bunch, 0.9ms, 5Hz
Beam current: 5.7mA in train
Bunch train: 369ns spacing

Beam Dump

Chicane 2

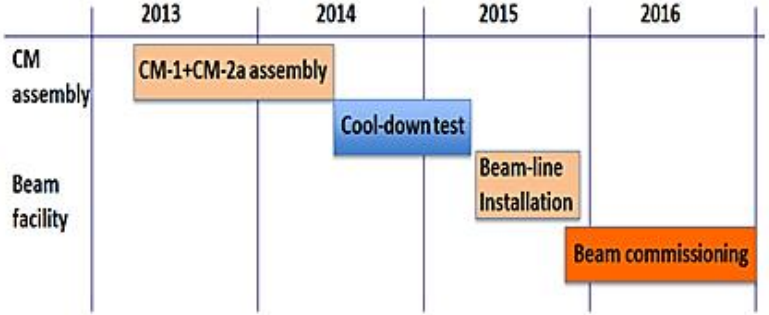
ILC-type Cryomodule (CM-1)
(8 SC cavities + SC-quad/BPM)
+
half-size Cryomodule (CM-2a)
(4 SC cavities)

Chicane 1

Capture Cryomodule
(2 SC cavities)

Photo-cathode RF-gun

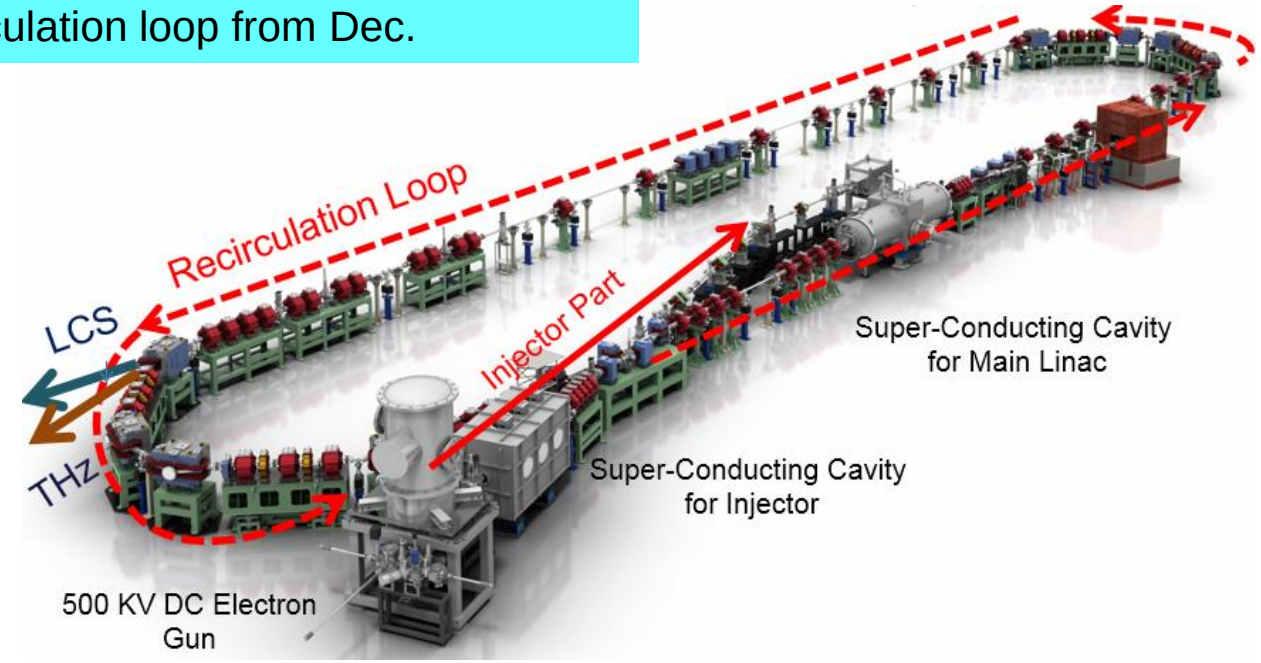
Plan of STF Start-up schedule



Compact Eenrgy Recovery Linac (cERL) Development

R&D for a future advanced light source

Fisical Year 2013
- Complete the construction of the hardware
- Commissioning of the beam operation
  - Injector part from April to June
  - Recirculation loop from Dec.



Fiscal Year 2014-2015(Application of cERL)
- Commissioning of LCS beamline
- Commissioning of THz beamline

Roadmap of Japanese High Energy Physics community