KEK Plans for J-PARC

Particle Physics at J-PARC

1. Accelerator status and plan
2. Physics program
   - Neutrino oscillation expriment
   - $K_L \rightarrow \pi^0 \nu\nu$ CP violation study
   - T violation in $K_{\mu 3}$
3. R&D for future
   - R&D on muon sources
   - Future neutrino program

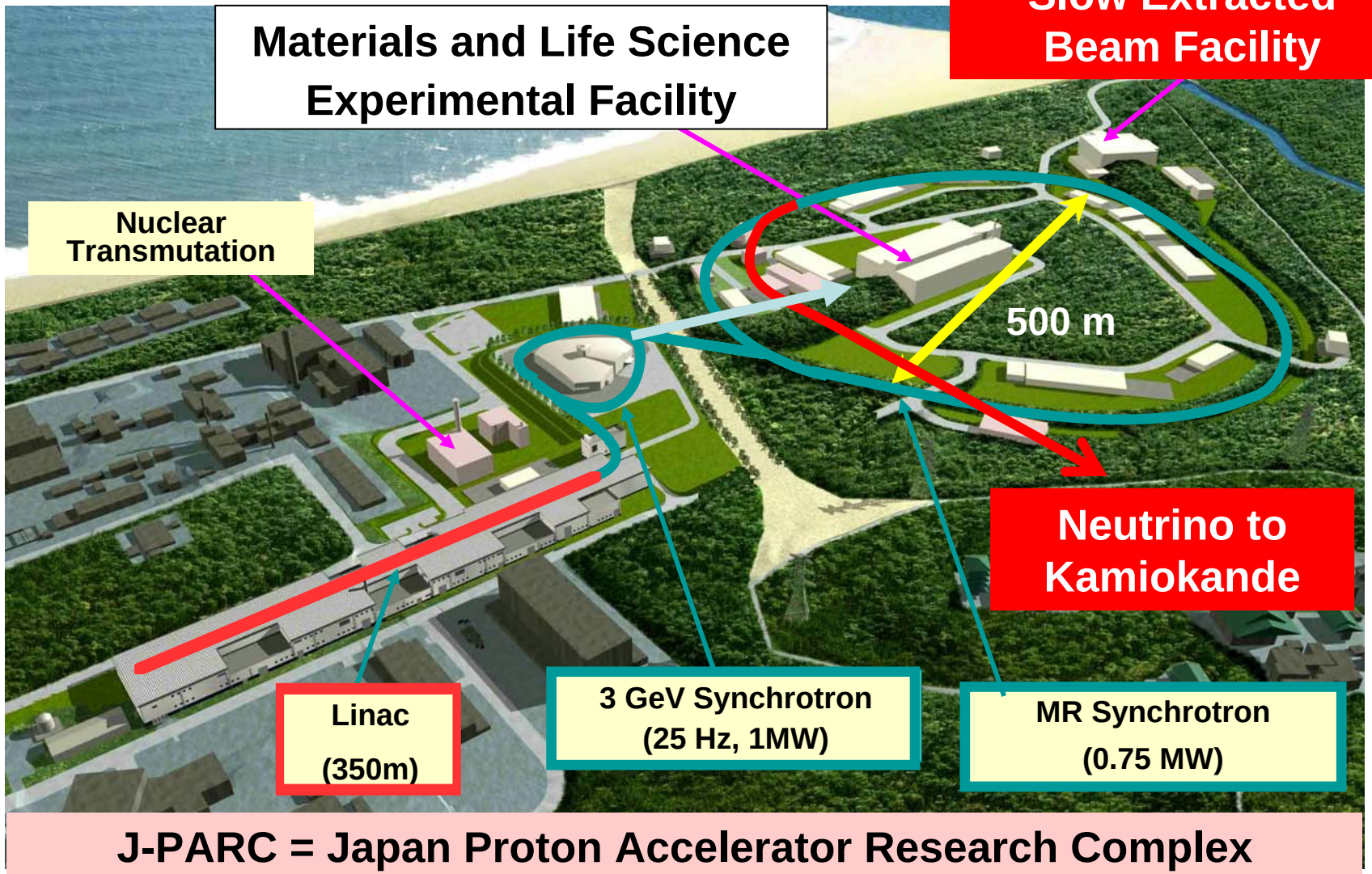
CERN-KEK Committee

March 29, 2010 at KEK

Koichiro Nishikawa

Institute for Particle and Nuclear Studies, KEK

J-PARC



J-PARC = Japan Proton Accelerator Research Complex

Joint Project between KEK and JAEA

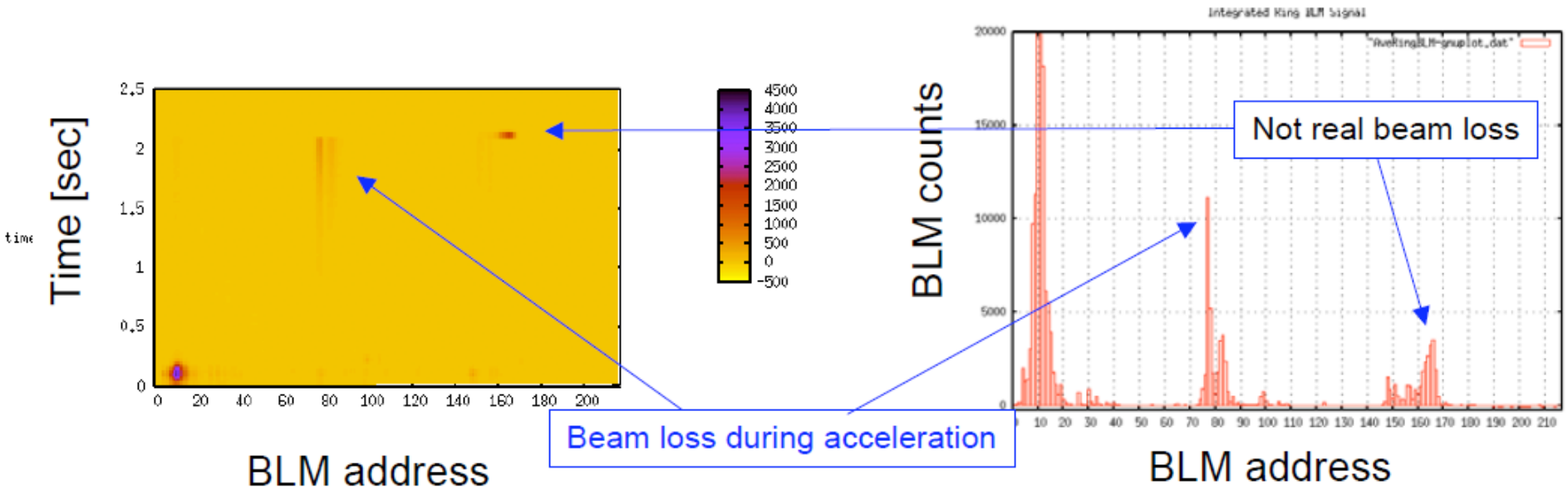
Accelerator Status and Plan

Fast Extraction (FX)

For continuous FX with ~100kW beam

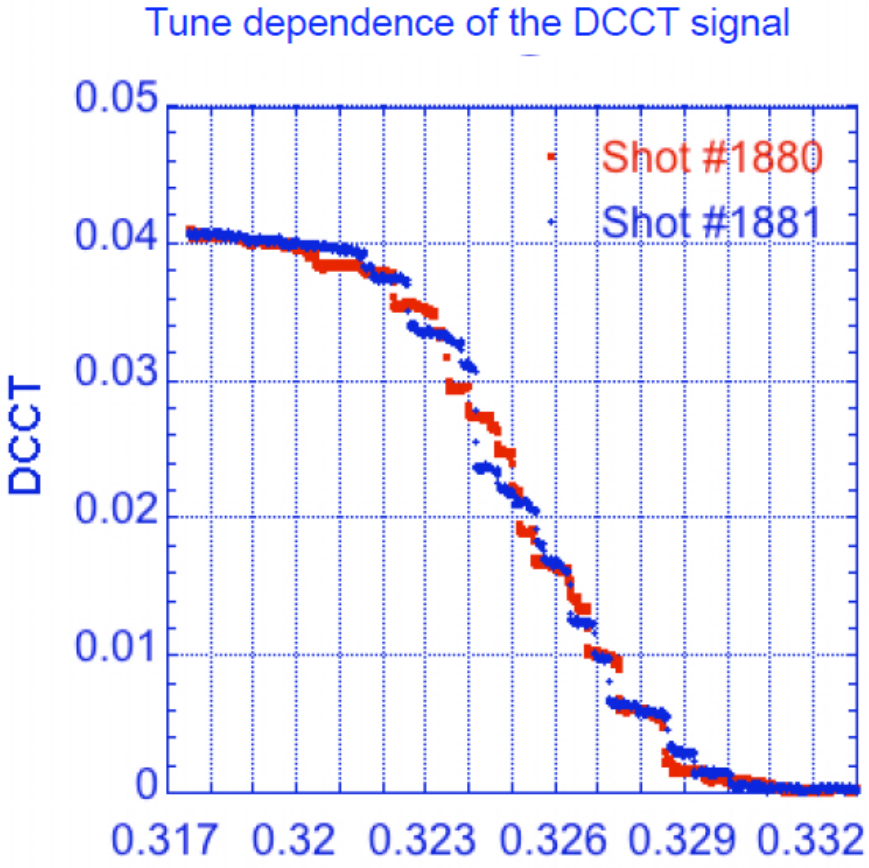
- LINAC/RCS are ready
  - MR100kW corresponds RCS300kW equiv protons/pulse.
- Beam loss studies in MR just started
  - ~100W loss already demonstrated

- **Beam loss during acceleration, etc. to be worked out to run at >100kW**

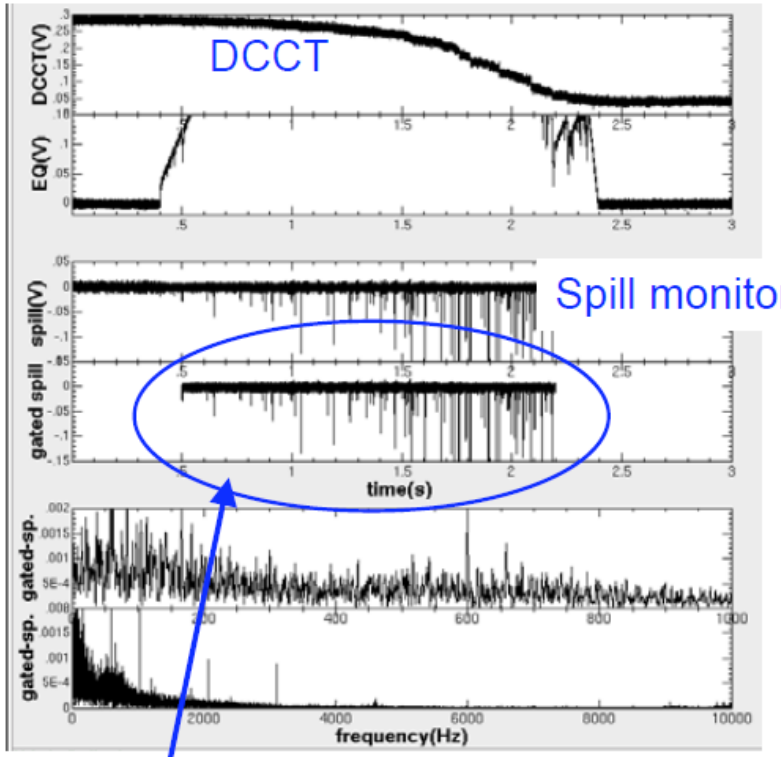


Slow Extraction

Spill structure Radioactivity by beam loss



Because of the tune fluctuation, the circulating beam decreases in the step-like shape



Extracted beam has many sharp peaks.

$$Duty = \frac{\left(\int_0^T Idt\right)^2}{\int_0^T dt \int_0^T I^2 dt} \qquad \sim 1\ \%$$

Summary

given by T. Koseki (accelerator facility) at ATAC March 12, 2010

FX:

- Continuous beam extraction of 30 kW in maximum to T2K experiment

-Start up high power beam operation

Demonstration of 100 kW operation in single shot mode.

SX:

- Continuous beam extraction of 1-2 kW to HD users
- Extraction efficiency study
- improvement of the spill structure:

- Correlation between beam loss and residual activation is studied.

Plan for JFY2010

- Study of Instability suppression by bunch-by-bunch feedback system
- Detailed comparison between measurements and simulation for 100 kW

FX:

- Beam delivery of 40 - 100 kW or higher to T2K experiment
- FX tuning with new kicker system

(Details of the kicker will be given by K. Koseki)

SX:

-Beam delivery of 5 kW to HD users

-For higher extraction efficiency :

Dynamic bump scheme will be adopted from 2010 Autumn RUN

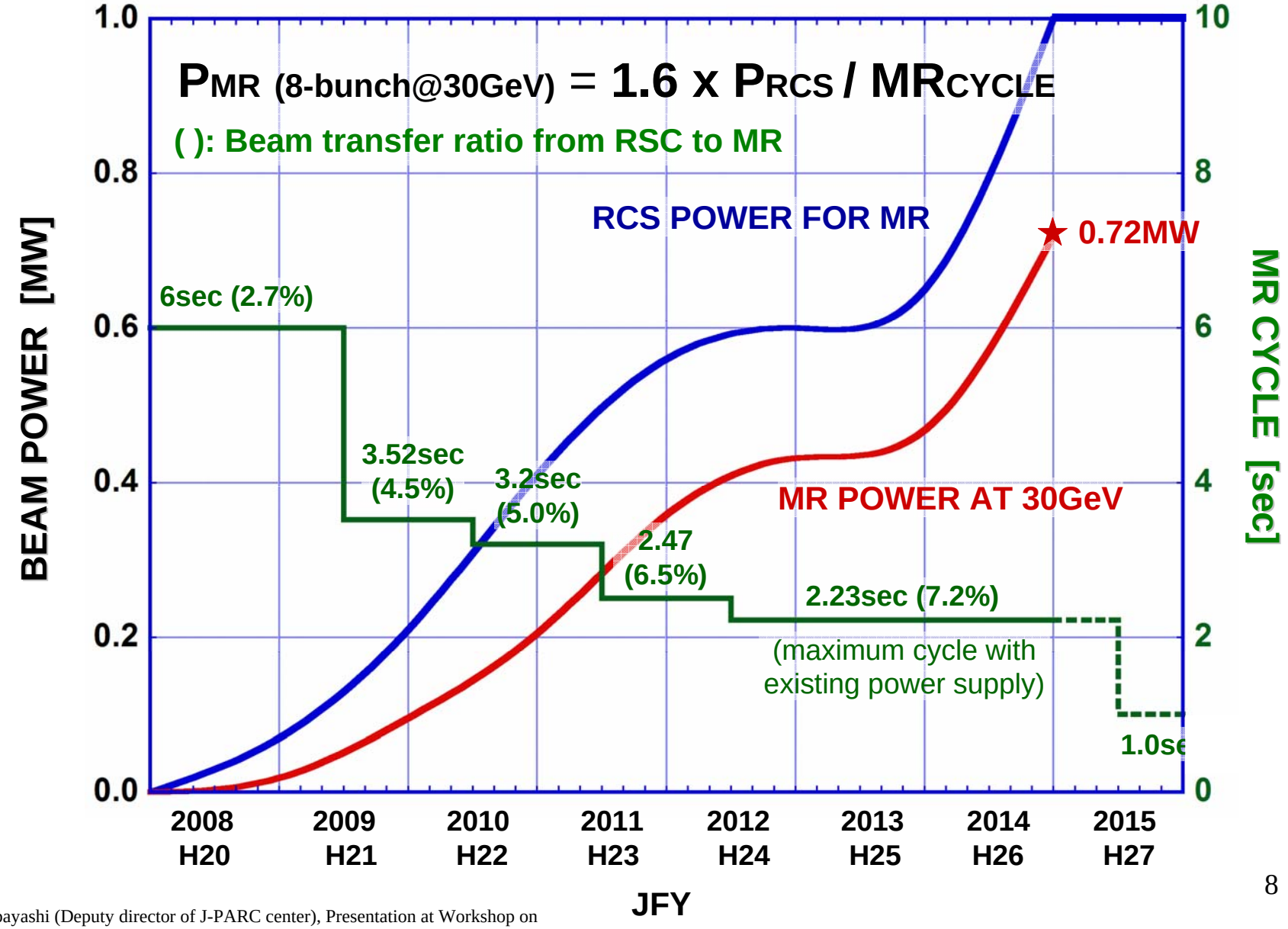
- For spill structure :

Main PS tuning to reduce 600 Hz ripple

Feedback with RF noise

Ripple cancellation system

AN EXPECTED BEAM POWER CURVES FOR RCS AND MR FAST BEAM EXTRACTION



H.Kobayashi (Deputy director of J-PARC center), Presentation at Workshop on Applications of High Intensity Proton Accelerators, Oct.19-21, 2009, FNAL

T2K experiment

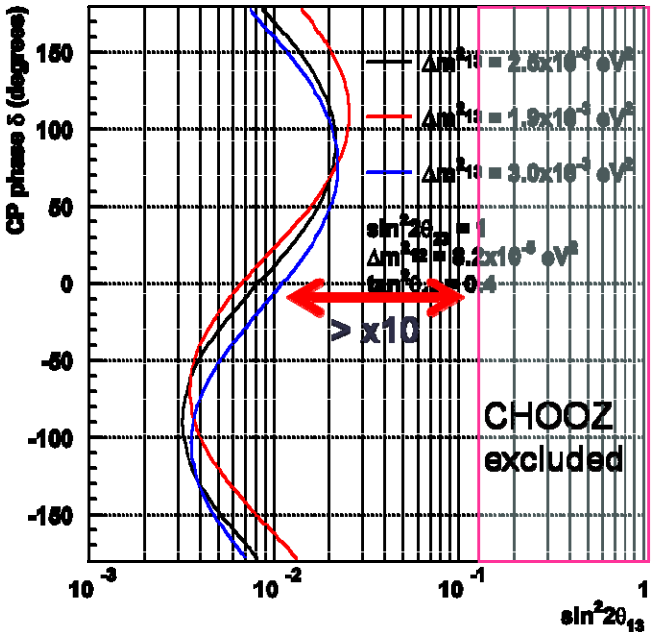
Tokai-to-Kamioka (T2K) long baseline neutrino oscillation experiment

Super-Kamiokande
(ICRR, Univ. Tokyo)

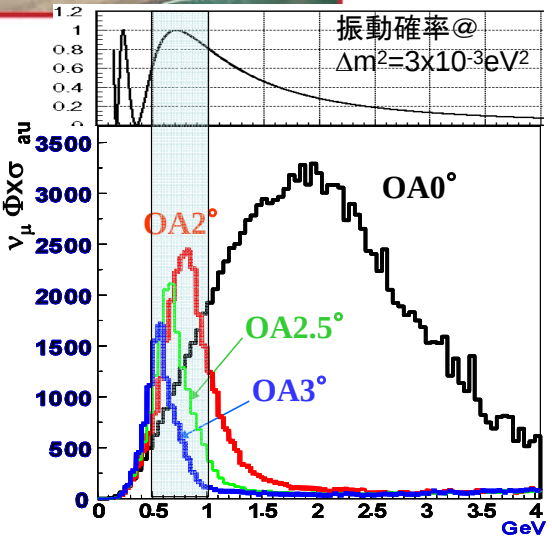
Now Running!

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

ν_e appearance (θ_{13})



- Goal
  - **Discover νμ →νe app.**
  - νμ disapp. meas.
- Intense narrow spectrum νμ beam
  - Off-axis w/ 2~2.5deg
  - Tuned at osci. max.
- Near detector
- Super Kamiokande



1600ν_μCC/yr/22.5kt (2.5deg)

The T2K Collaboration

~500 members, 62 institutes, 12 countries

Canada
TRIUMF
U. Alberta
U. B. Columbia
U. Regina
U. Toronto
U. Victoria
York U.

France
CEA Saclay
IPN Lyon
LLR E. Poly.
LPNHE Paris

Germany
U. Aachen

Italy
INFN, U. Roma
INFN, U. Napoli
INFN, U. Padova
INFN, U. Bari

Japan
Hiroshima U.
ICRR Kamioka
ICRR RCCN
KEK
Kobe U.
Kyoto U.
Miyagi U. Edu.
Osaka City U.
U. Tokyo

Poland
A. Soltan, Warsaw
H.Niewodniczanski, Cracow
T. U. Warsaw
U. Silesia, Katowice
U. Warsaw
U. Wroklaw

Russia
INR

S. Korea
N. U. Chonnam
U. Dongshin
U. Sejong
N. U. Seoul
U. Sungkyunkwan

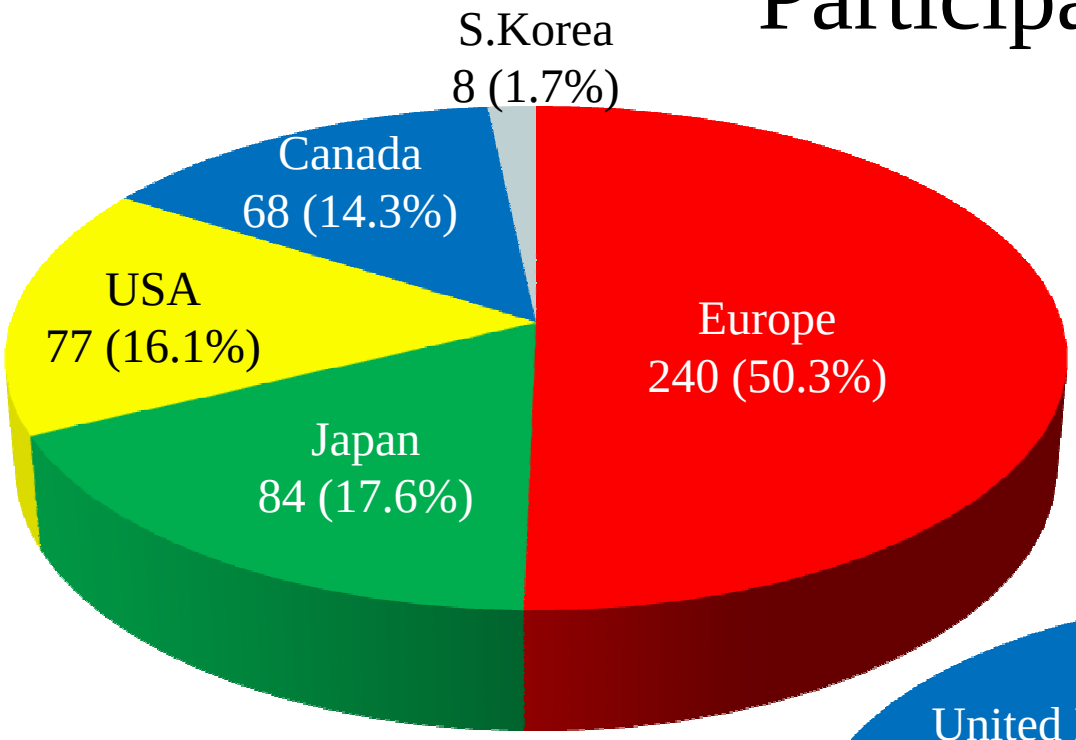
Spain
IFIC, Valencia
U. A. Barcelona

Switzerland
U. Bern
U. Geneva
ETH Zurich

United Kingdom
Imperial C. London
Queen Mary U. L.
Lancaster U.
Liverpool U.
Oxford U.
Sheffield U.
Warwick U.
STFC/RAL
STFC/Daresbury

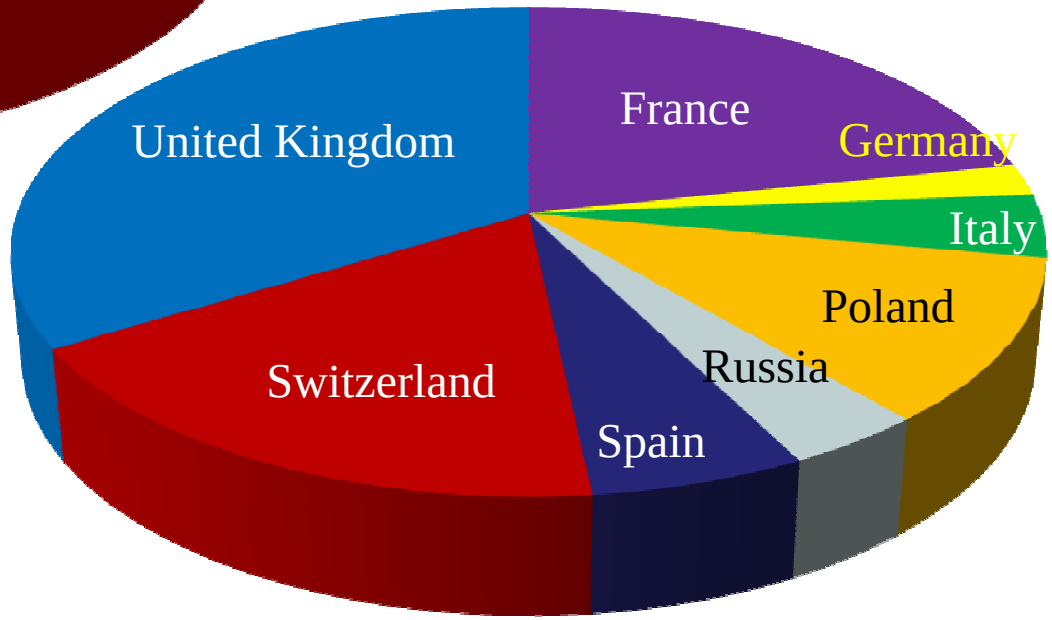
USA
Boston U.
B.N.L.
Colorado S. U.
Duke U.
Louisiana S. U.
Stony Brook U.
U. C. Irvine
U. Colorado
U. Pittsburgh
U. Rochester
U. Washington

Participants for T2K

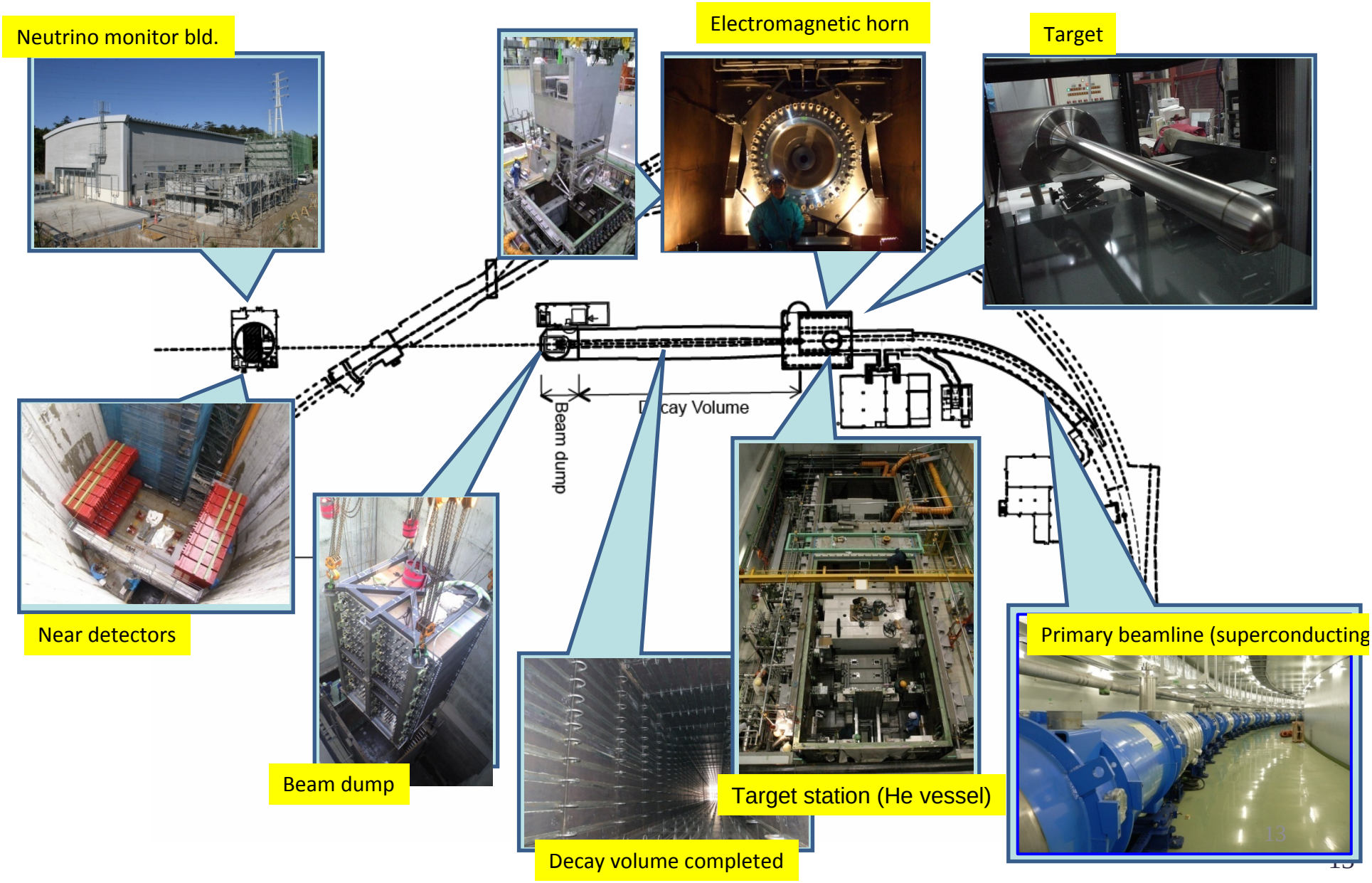


ALL

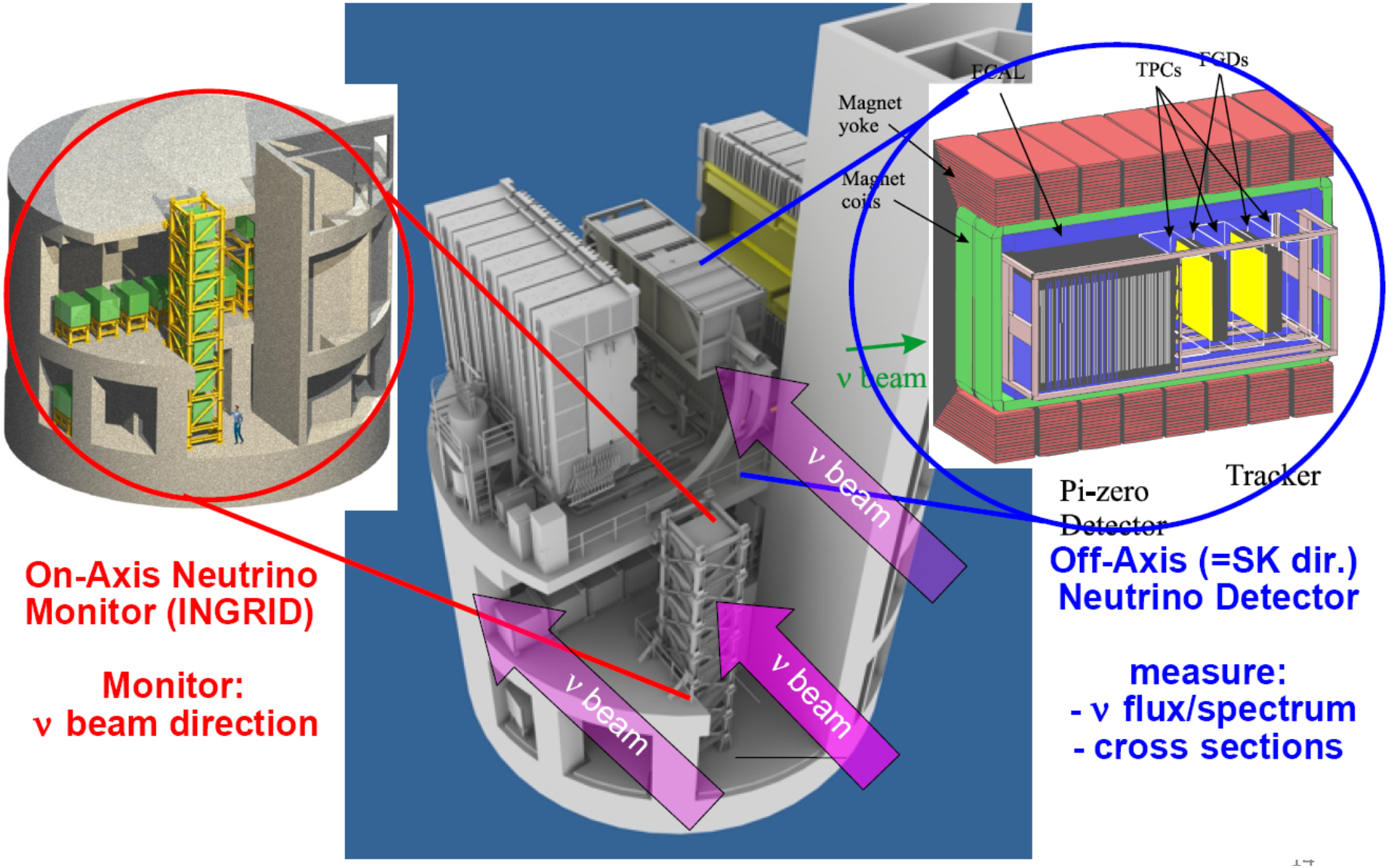
Europe



Neutrino facility in J-PARC



2 Near Detectors

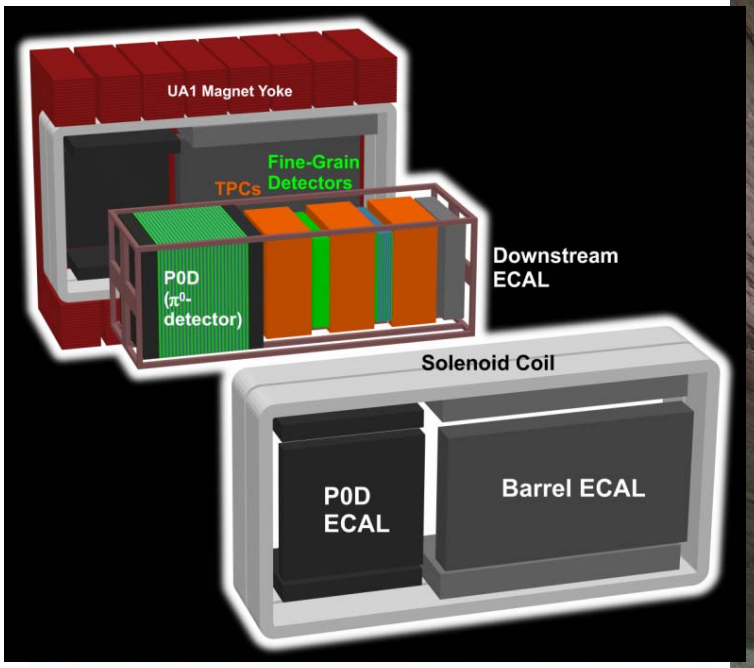


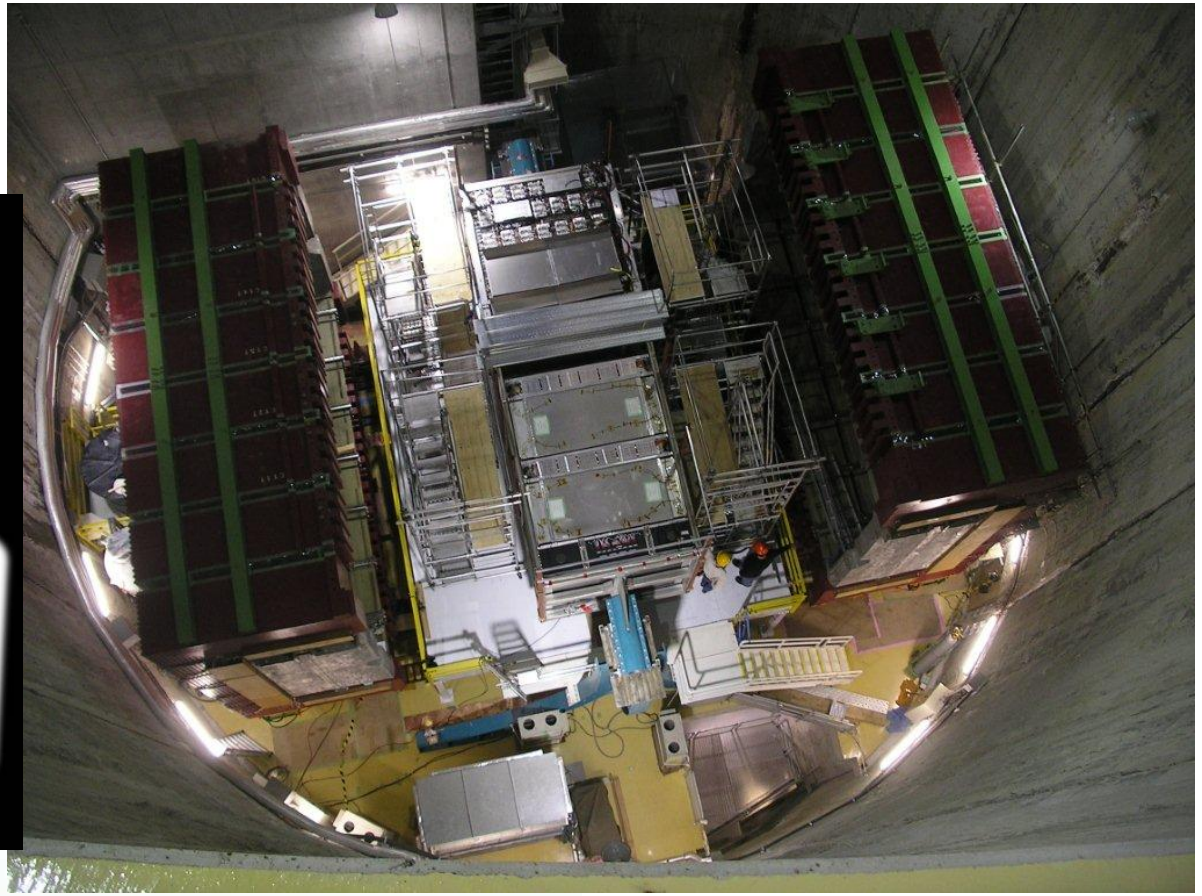
CERN Support to T2K(RE13)

- CERN NA61 Experiment (π, K yields in p+C at 30GeV)
- CERN test beam for detectors
- Donation of UA1/NOMAD magnet
- Micromegas production and test by CERN TS/DEM group
- Various technical, administrative support on detector preparation, especially for UA1/NOMAD magnet related issues
- Infrastructure for detector preparation
- CERN-KEK cooperation on super conducting magnet for neutrino beam line

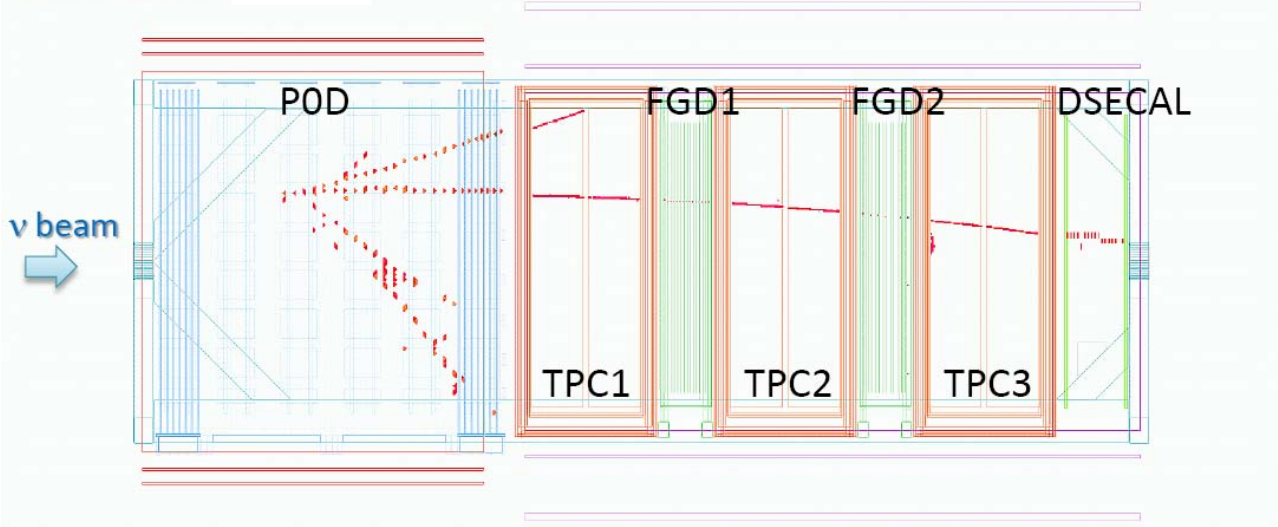
We appreciate generous support from CERN.

OFF axis detector





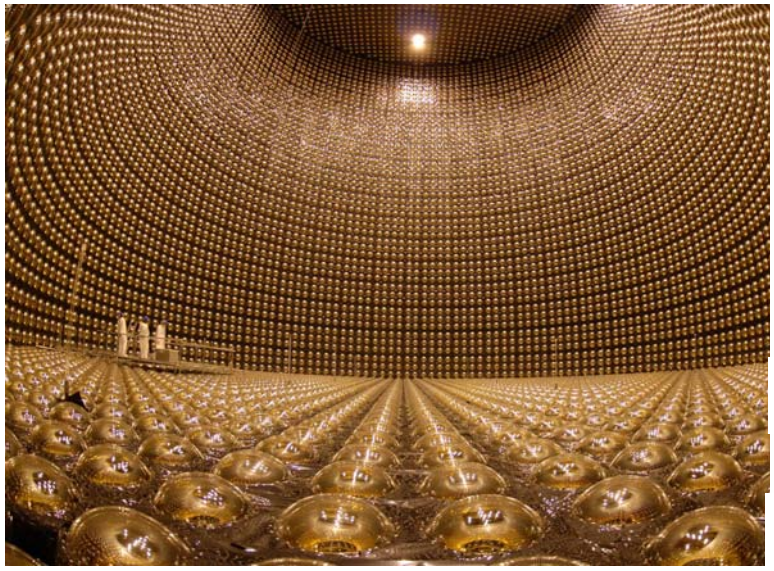
Magnet on (0.19T)



- First neutrino interaction w/ magnet operation

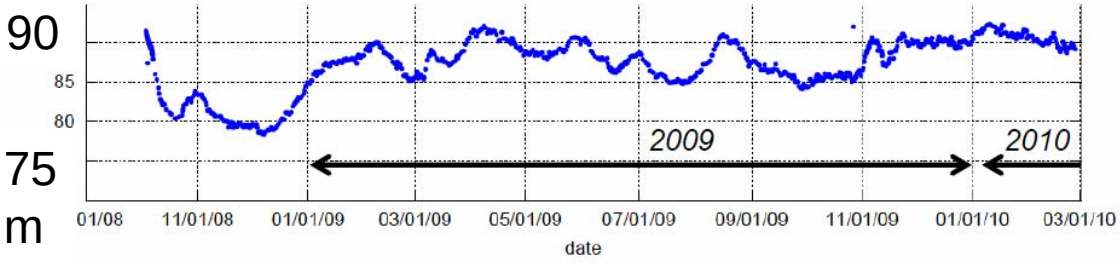
Far Detector: SK-IV

- 50kt Water Cherenkov detector.
- 20’ PMT×10,000 + Anti counter PMT×2000 : 40% Photo coverage
- New readout electronics is installed in 2008 summer.
  - Stable & dead time less DAQ system
- Beam related events are selected by event timing using GPS system.
  - Beam timing is sent via network and used in semi-online event selection.

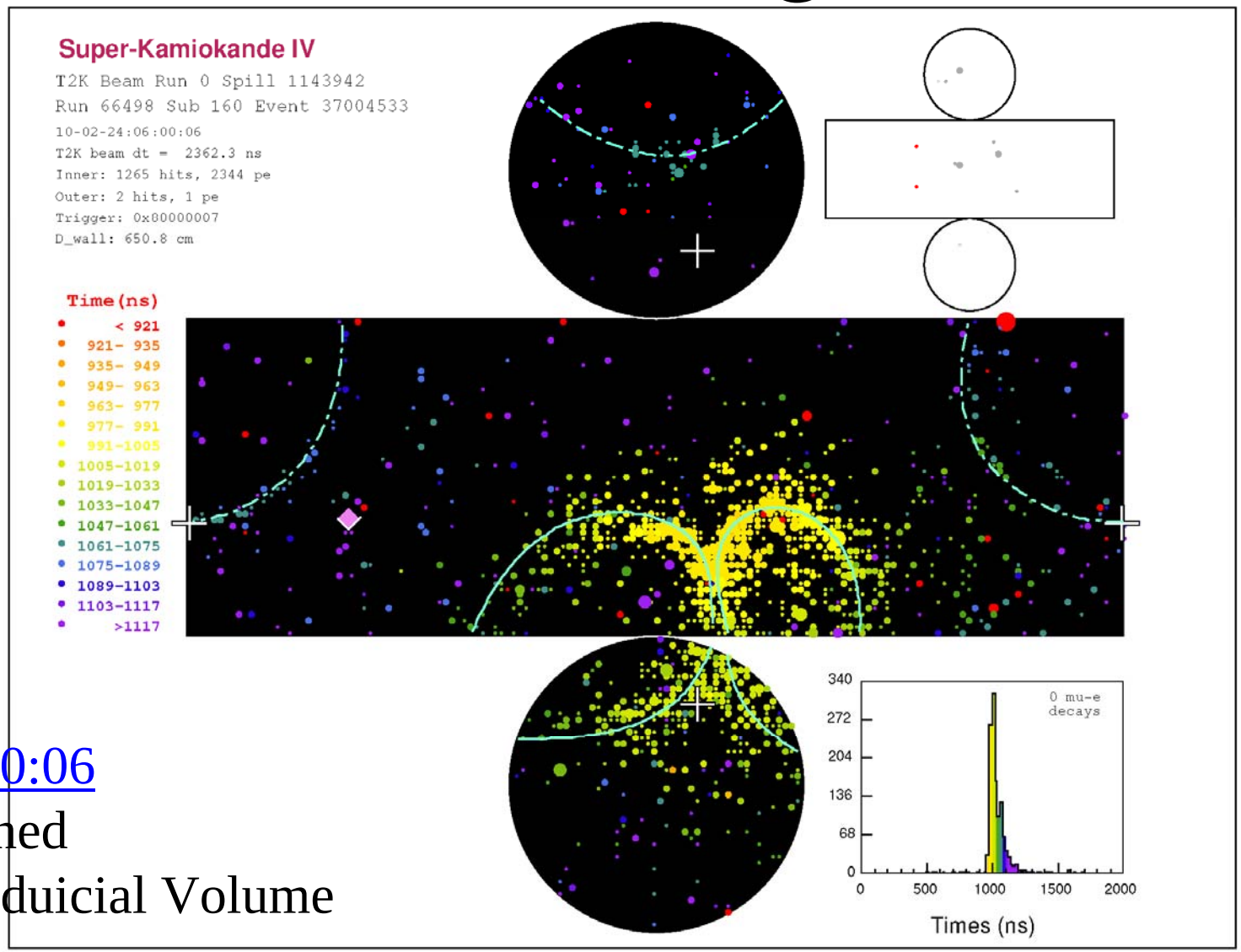


SK detector status

- *SK detector is really stable and of high efficiency*
  - *SK efficiency during beam run is >99% in run 29 and 30.*
  - *Water quality (light attenuation length) is 90m and is stable for one year.*



First ν event candidate @ SK



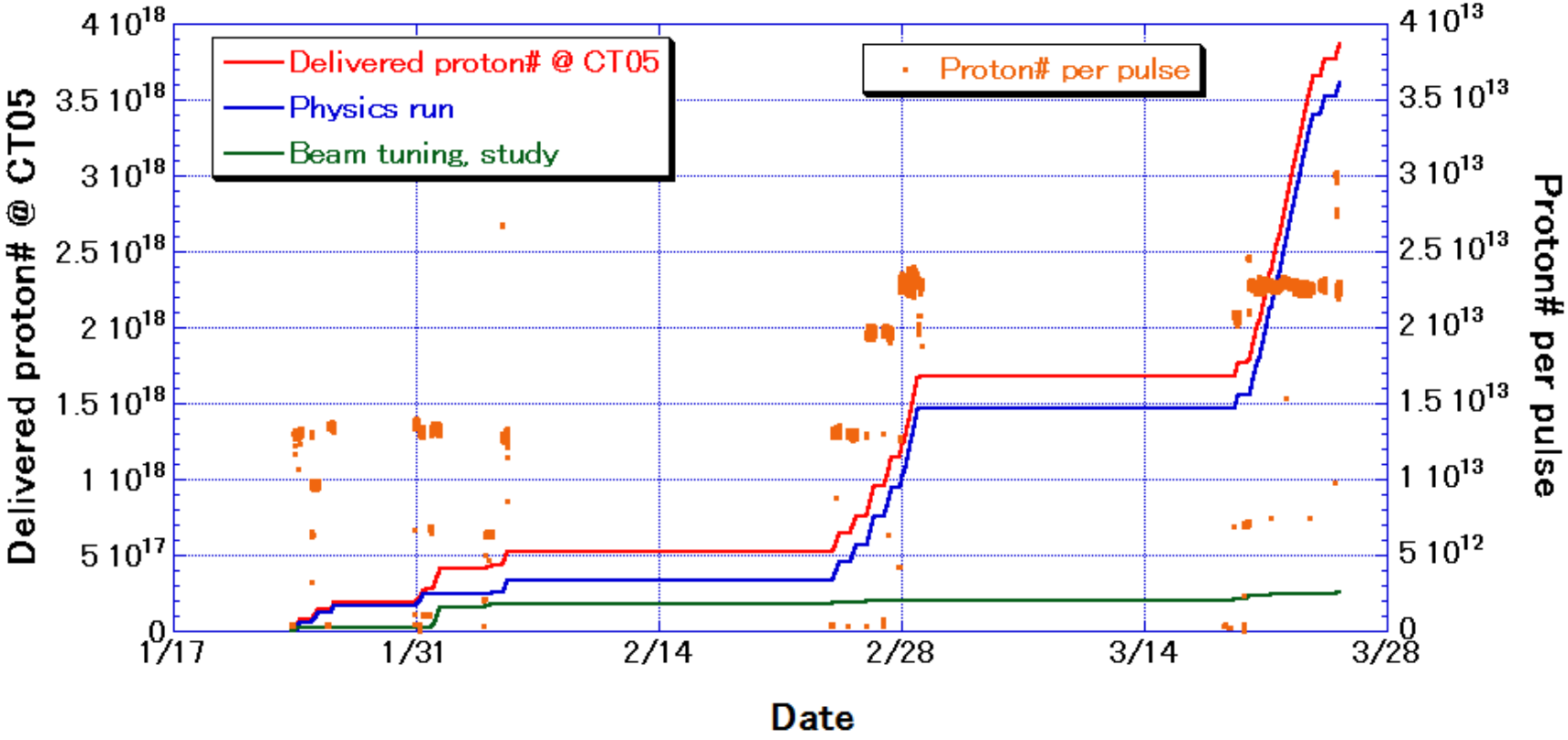
[2010/2/24 6:00:06]

- Fully contained
- Inside the Fiduicial Volume
- On timing

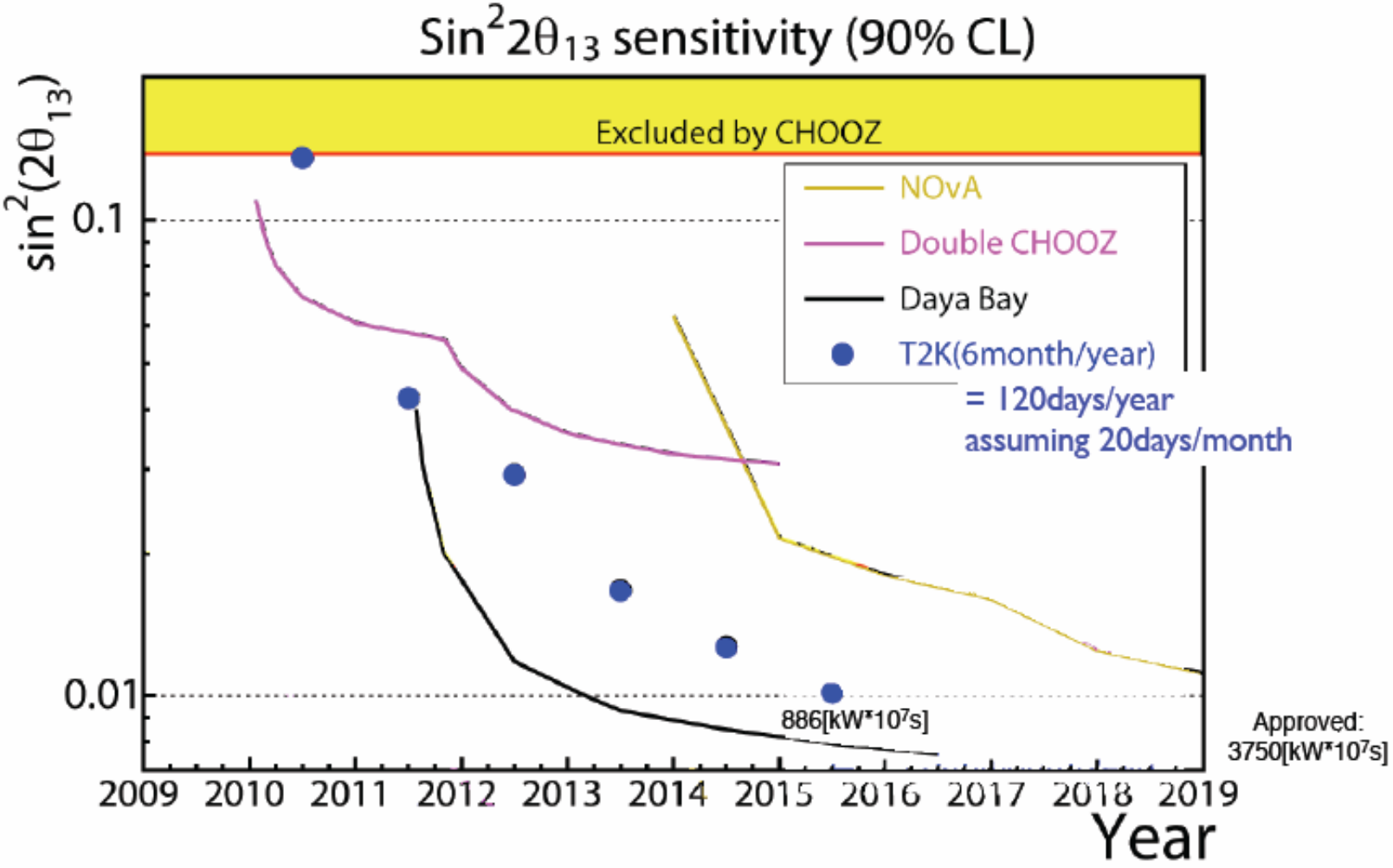
Many milestones have been cleared

- In JFY2008
  - Beamline construction completed as scheduled
- Apr-May, 2009
  - First beam on April 23 to neutrino beamline (as scheduled)
  - Beam commissioning
- Jun-Oct,2009 (scheduled Summer shutdown)
  - 2^{nd} and 3^{rd} horn installed
  - INGRID completed & commissioning
- Nov-Dec, 2009
  - Off-axis detector completed and started commissioning (except side ECAL)
  - First neutrino event in INGRID (Nov) & Off-axis (Dec)
  - Beam commissioning completed
- Jan-, 2010
  - Off-axis detector & UA1 magnet commissioning
  - 1^{st} neutrino event in off-axis detector w/ magnetic field
  - Physics data taking started in January
  - 1^{st} SK event on Feb.24

Delivered proton# during Jan-Mar



Delivered for “physics run” ~3.6e18 protons



PAC set T2K as the top priority experiment for 2010-2011 MR program

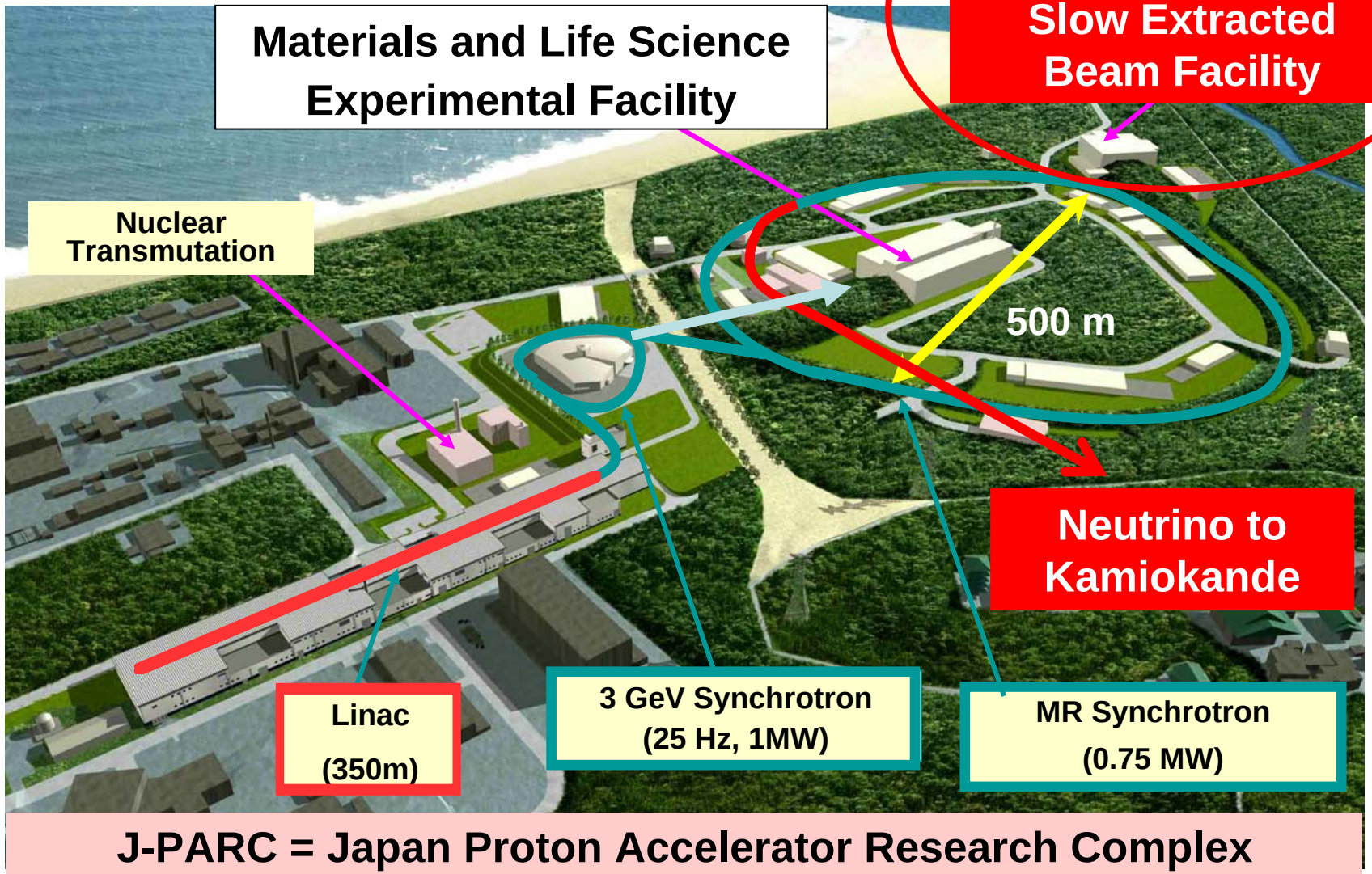
Jan 2010 - June, 2010 20kW ~100kW

Nov 2010 - June 2011 ~150kW (even higher if possible)

Total of 6~7month, >120 days (net) of data taking

J-PARC

Physics at slow extraction facility



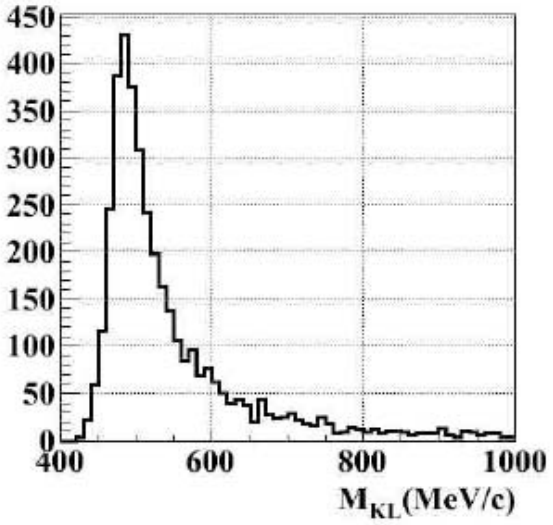
J-PARC = Japan Proton Accelerator Research Complex

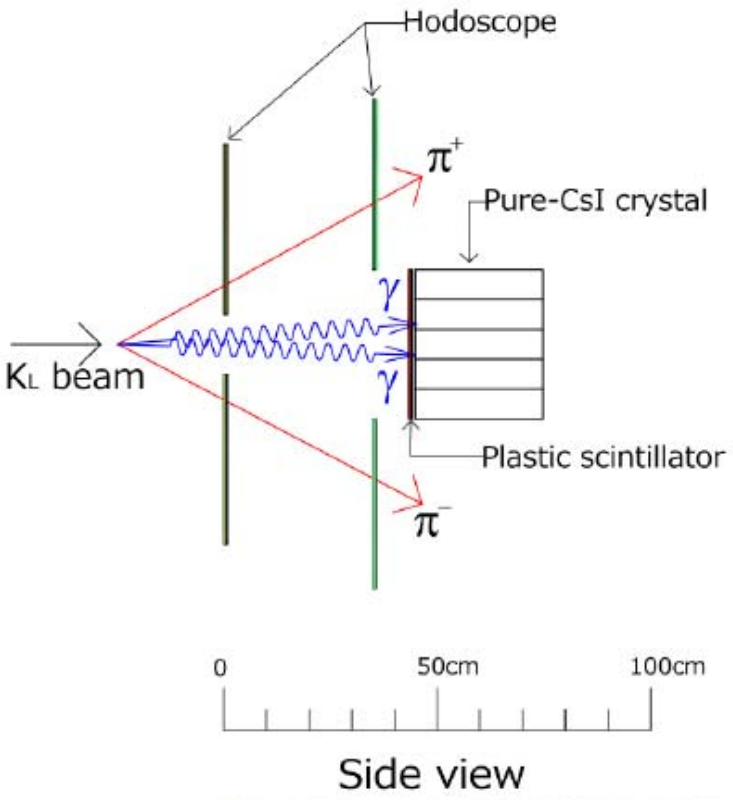
Joint Project between KEK and JAEA

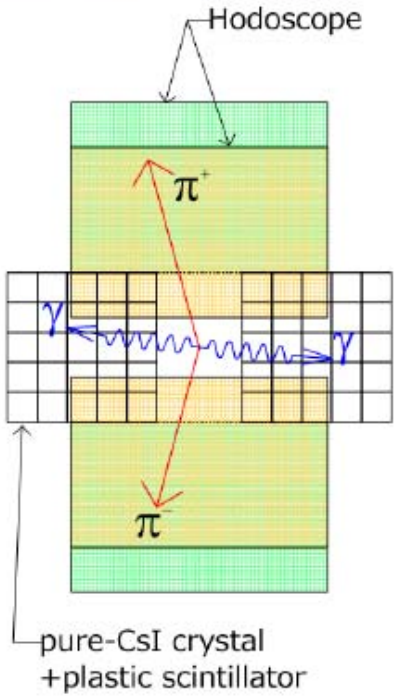
KOTO

Search for CP violation sources in K_L
above the second order weak interaction

$K_L \rightarrow \pi^+\pi^-\pi^0$ decay (13%)

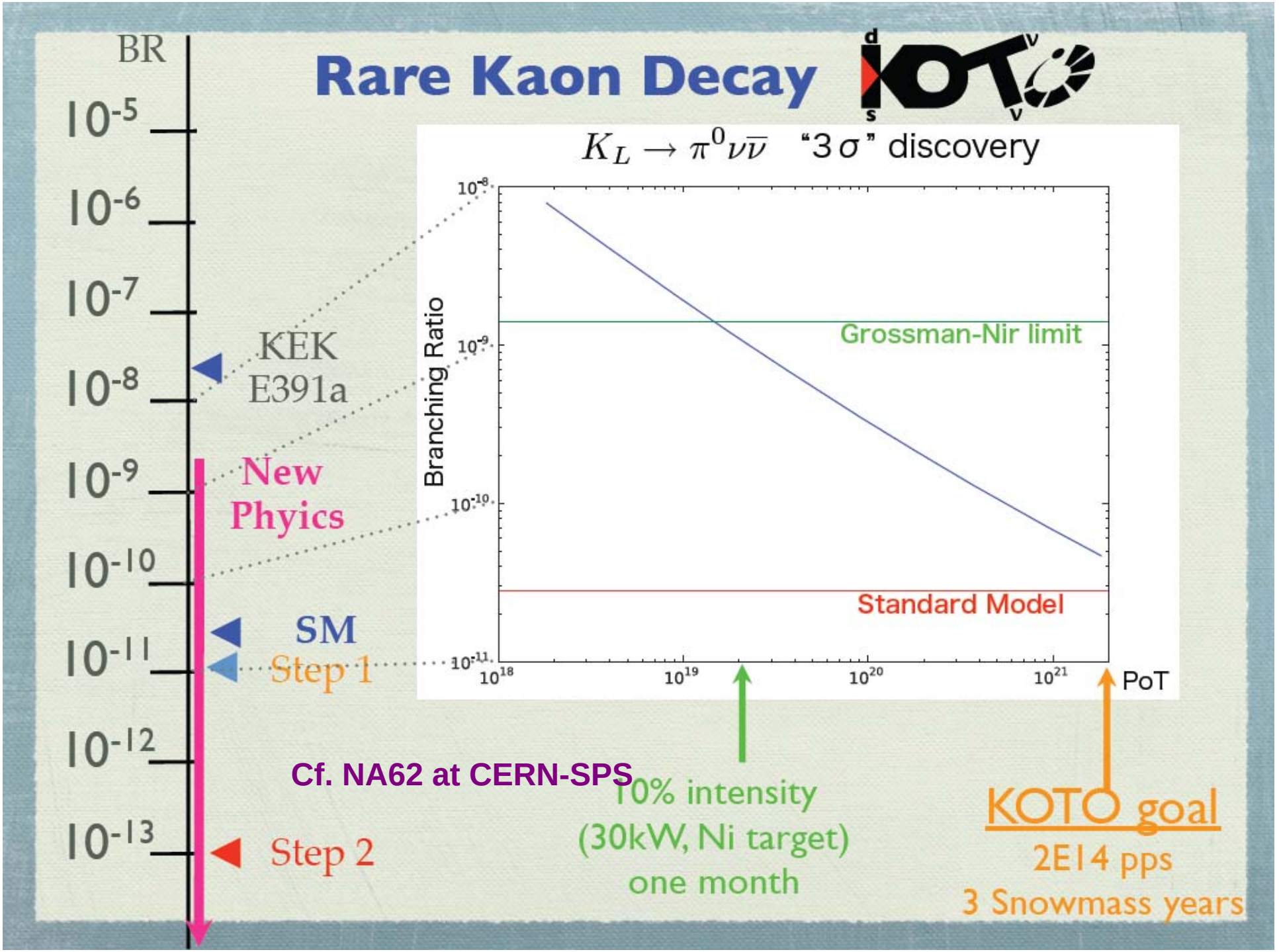






2.6 E16 protons on target
in February 2010 [29 hrs]
(1kW beam, Ni target, w/ He bag)

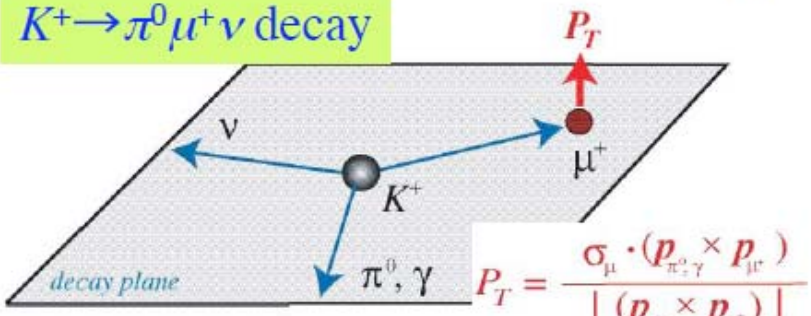
Rare Kaon Decay



by courtesy of J. Imazato(KEK)

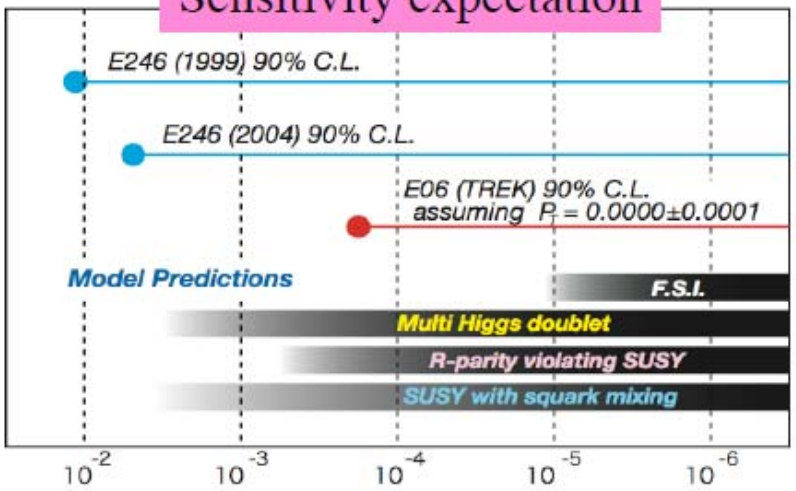
E06 (TREK):Search for T-violating Transverse μ^+ polarization in $K_{\mu 3}$

$K^+ \to \pi^0 \mu^+ \nu$ decay

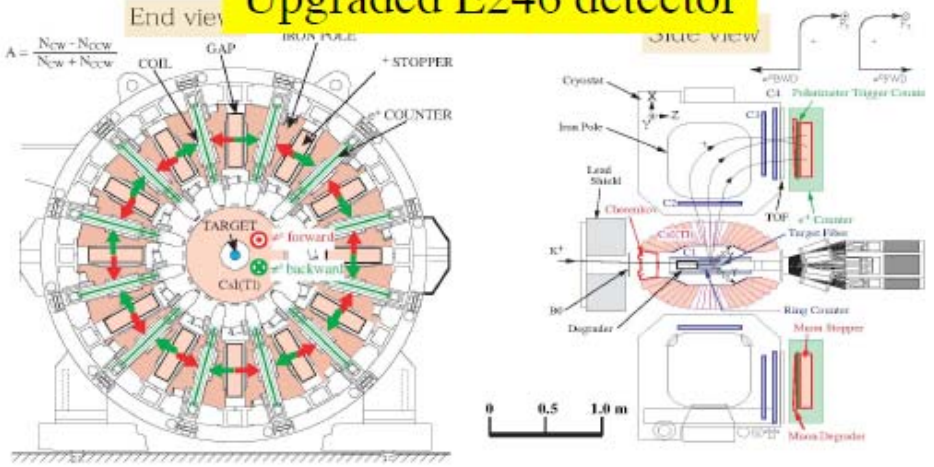


- P_T is T-odd, and P_T(FSI) < 10^{-5}
  Non-zero P_T is a signature of T violation.
- P_T is a sensitive probe of CP violation beyond the SM.

Sensitivity expectation



Upgraded E246 detector



- *TREK experiment aims for a sensitivity of 10^{-4} (assuming 270 kW)*
- *Status=Stage-1 approval; Now detector element R&D*
- *K1.1BR beam will be ready soon and commissioned in October*

R&D for future

Muon experiments R/D

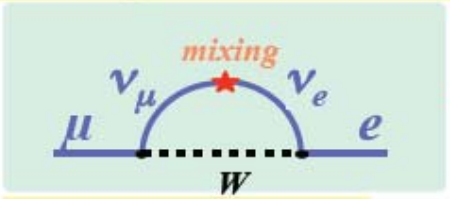
g-2, μ–e conversion

by courtesy of S. Mihara(KEK)

COMET

μ-e conversion search at J-PARC

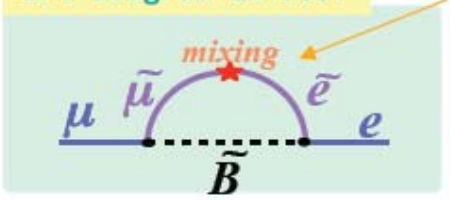
LFV diagram in Standard Model



$\propto (m_\nu/m_W)^4$

Very Small (10^{-52})

LFV diagram in SUSY



Large top Yukawa coupling

Sensitive to new Physics beyond the Standard Model

1s state in a muonic atom

ν-less μ capture (=μ-e conversion)

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

ΔL_μ=-1 ΔL_e=+1

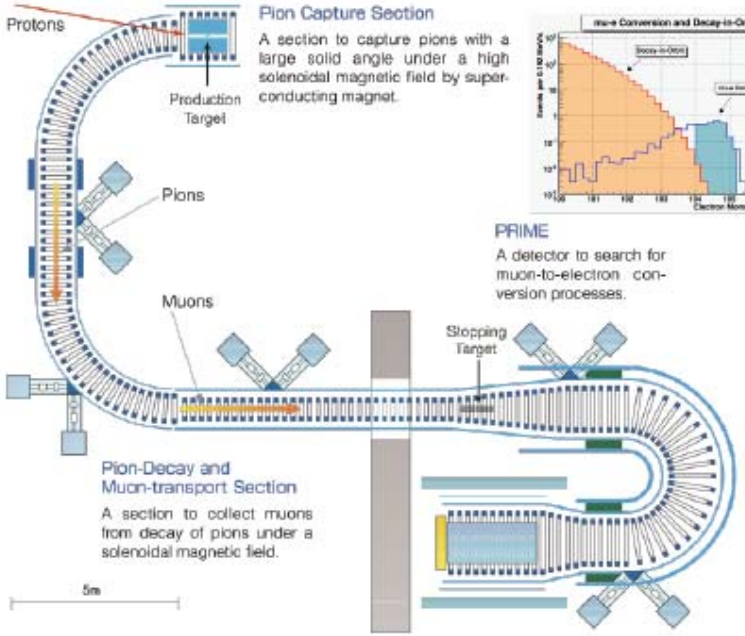
muon decay in orbit

$\mu^- \rightarrow e^- \nu \bar{\nu}$

nuclear muon capture

$\mu^- + (A,Z) \rightarrow \nu_\mu + (A,Z-1)$

$\Delta L_\mu = \Delta L_e = 0$

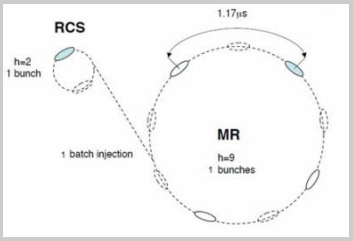


- Signal: electron with $E_{\mu e} \sim m_\mu - B_{\mu,,} \sim 105$MeV for Al tgt
  - B_μ: binding energy of the 1s muonic atom
- No SM background
- Clear evidence of new physics when observed
- Current best limit by SINDRUM II, 7×10^{-13}
- COMET goal 10^{-16} with 8GeV 50kW beam, 2×10^7s DAQ

- Proposal 2008, J-PARC PAC stage-1 approval 2009
- 51 collaborators from 14 institutes
- R&D in progress

COMET Activity Status

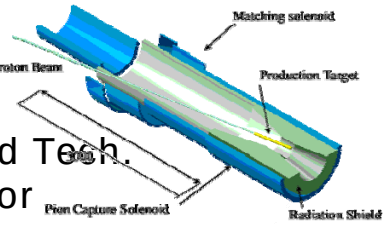
- **Beam Extinction Study**
  - Abort line measurement



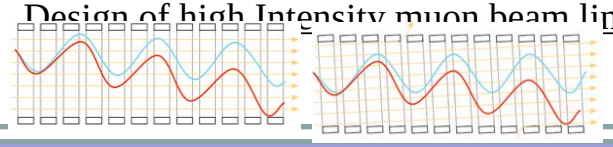
•Single bunch, single shot operation of MR
•Count the number of protons in the EMPTY bucket in front of the filled one

  - Secondary beam line measurement
    •Measure secondary particle time structure relative to a reference signal from the MR
    •MR operation with empty buckets
    •Bunched slow extraction

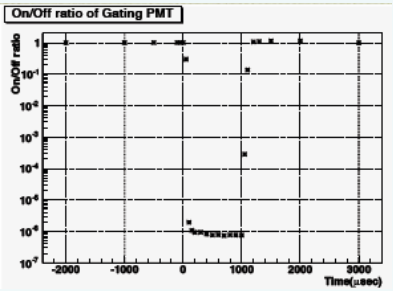
- **Super-conducting solenoid**
  - Pion capture solenoid
    •B=5T
    •Radiation transparent
    •Technology
      •Detector Solenoid Tech.
      •NbTi+Al conductor
      •Indirect pipe cooling
      •Conductor development in 2009
      •Test coil construction and test in 2-3 years



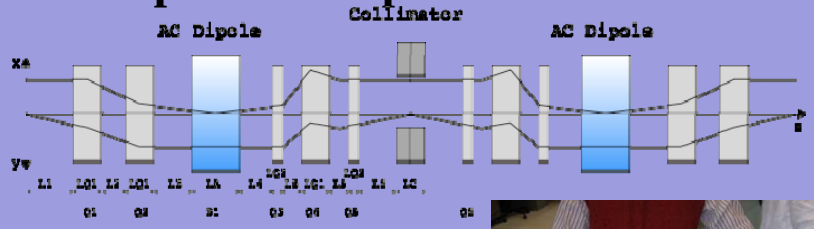
  - Design of high Intensity muon beam line



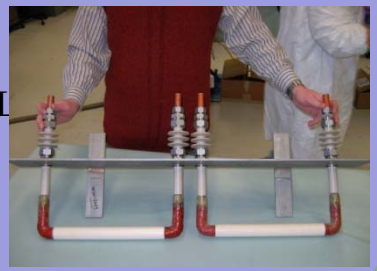
- **Extinction monitoring device development**
  - Gating PMT for a Gas Cerenkov detector, 1MHz switching with 10^6



- **AC-dipole development**



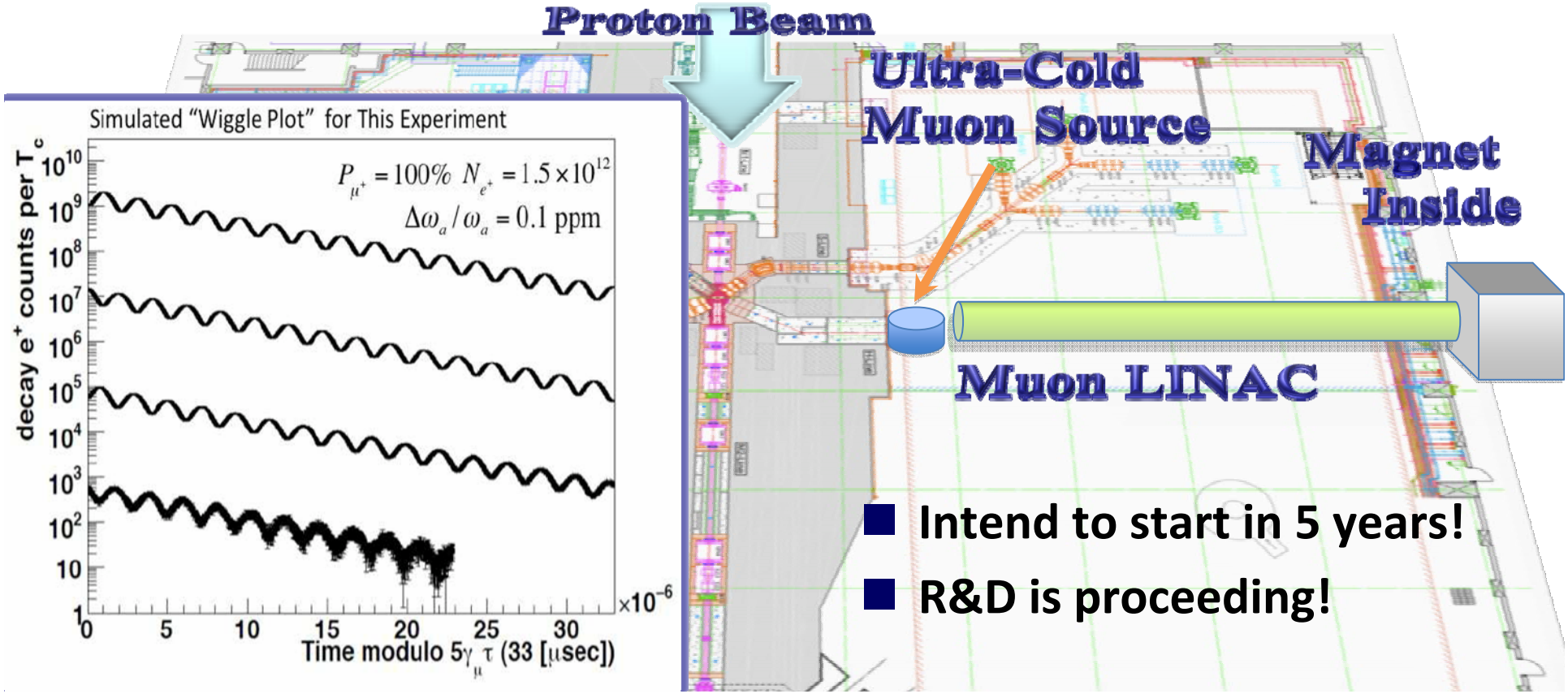
  - Collaboration with FNAL



•1st version corona-tested
•2nd version built

Muon g-2/EDM at 3GeV RCS facility

- Proposal submitted to J-PARC PAC
  - Many homework!
  - R&D efforts are supported by KEK (and other institutes e.g. RIKEN)
- LOI presented at MuSAC and discussion with MLF started
- Strong support from J-PARC is necessary to realize the experiment!



Future neutrino program

Beyond T2K

- Lepton Sector CP Violation
  - Search for CP violation in Neutrino Oscillation Process
    - Conclude Mass Hierarchy of Neutrinos
    - Examine Matter Effect in Neutrino Oscillation Process
- Proton Decay
  - $p \rightarrow \nu K$
  - $p \rightarrow e \pi^0$

- SK has accumulated 91kton·year @ 40%, 50 kton·year @ 20% photo-cathode coverage and keep accumulating

- **MR Power Improvement**
- **New detector concept, new way of looking for the phenomena**

MR improvement Scenario toward multi-MW power frontier machine
— KEK Roadmap —

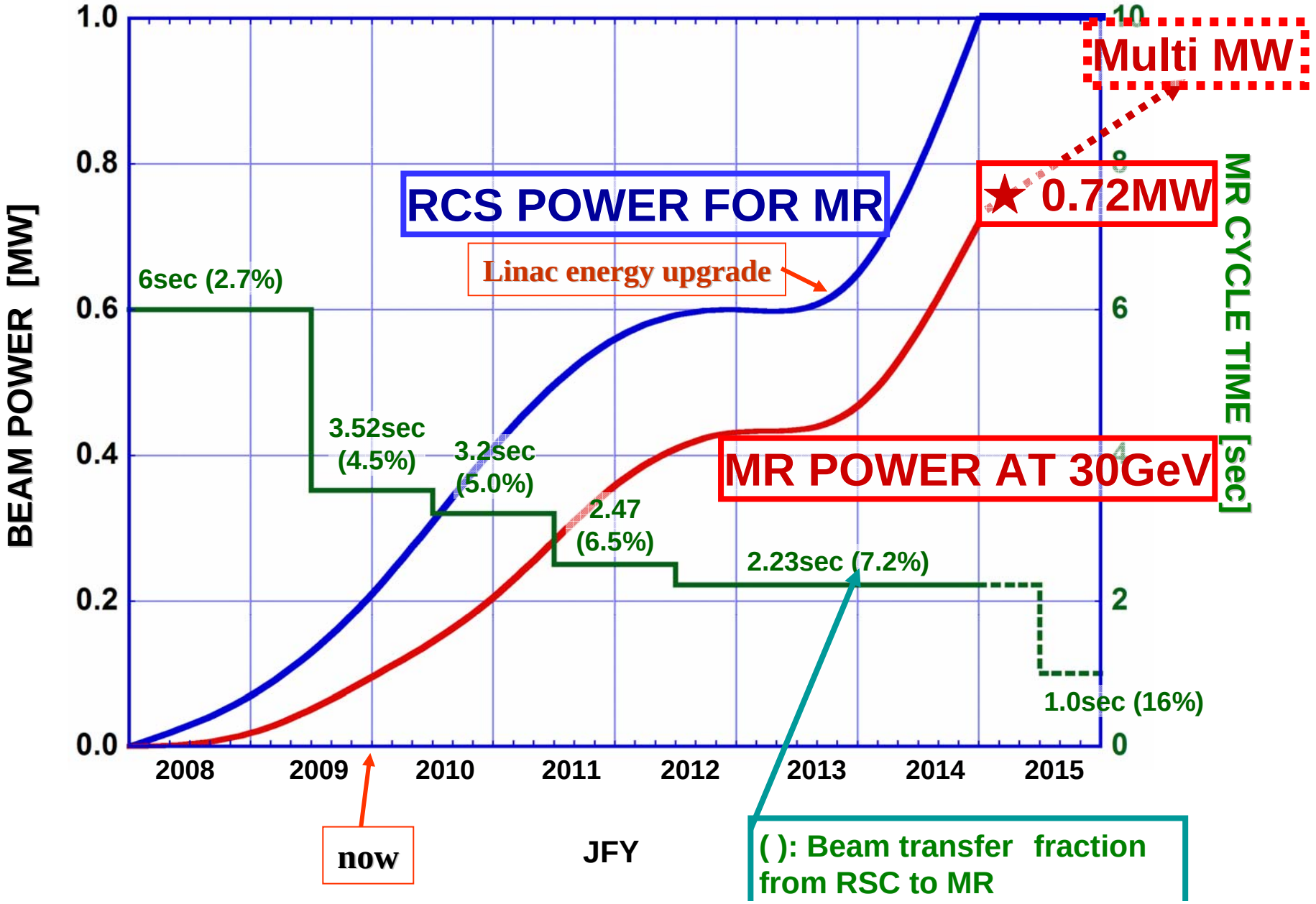
	Day1 (now trying)	Next Step	KEK Roadmap
Power(MW)	0.1	0.45	1.66
Energy(GeV)	30	30	30
Rep Cycle(sec)	3.5	3 ~ 2	1.92 (→ 0.5 ?)
No. of Bunch	6	8	8
Particle/Bunch	1.2×10^{13}	$<4.1 \times 10^{13}$	8.3×10^{13}
Particle/Ring	7.2×10^{13}	$<3.3 \times 10^{14}$	6.7×10^{14}
LINAC(MeV)	181	181	400
RCS	h=2	h=2 or 1	h=1 ?

Rapid cycling
- High power RF
- Magnet P.S.

Key technology to develop

AN EXPECTED BEAM POWER CURVES for FX

More work in technical & financial aspects at JAEA and KEK



Beyond T2K

Quest for the Origin of Matter Dominated Universe

T2K
(2009~)

Discover
n_e app.

Neutrino
Anti-Neutrino meas.

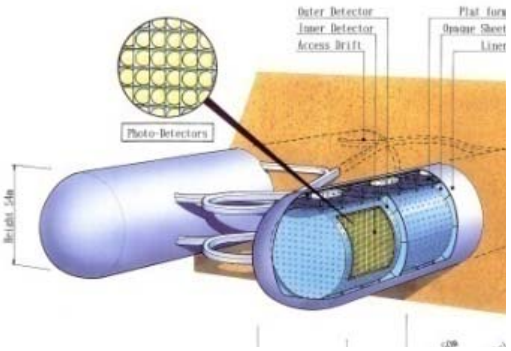
Intensity Upgrade

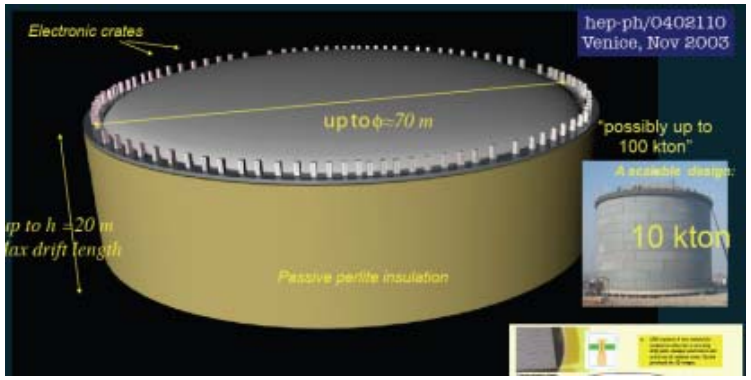
Detector R&D

Tech.
Choice

Large det.
Construction

CPV search
Proton decay





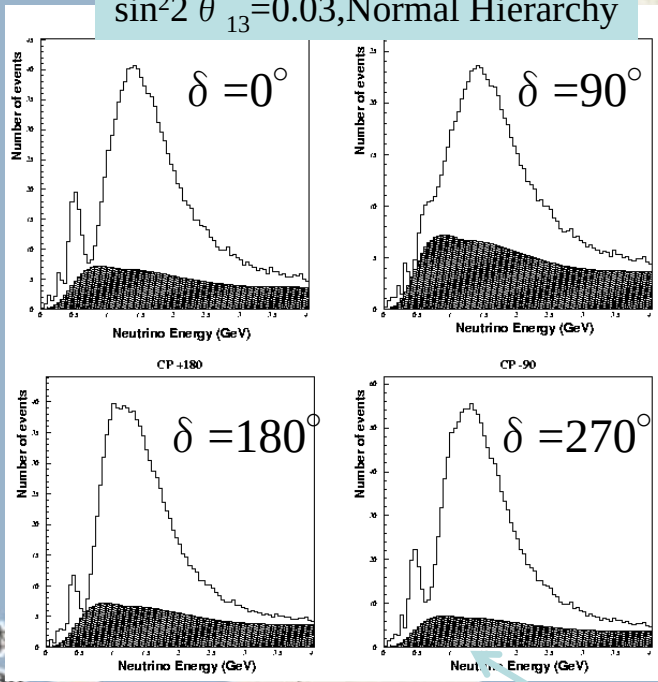
A Scenario

- Cover 1st and 2nd Maximum
- Neutrino Run Only 5Years × 1.66MW
- 100kt Liq. Ar TPC
  - Good e/π^0 discrimination
  - Good multi-track measurement

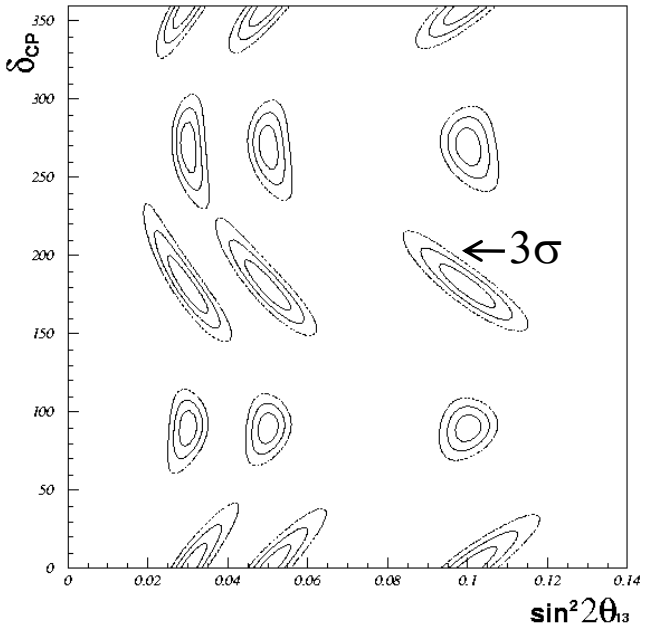
→Reconstruction of wide energy range

ν_e Spectrum

$\sin^2 2\theta_{13}$=0.03,Normal Hierarchy



CP Measurement Potential



Okinoshima

Beam ν_e Background

658km
0.8deg. almost On-axis
Wide band

NP08, arXiv:0804.2111

J-PARC PAC recommendation

Beam test of LAr
Charged particle beam

6. PROPOSAL EVALUATIONS

1. **P32:** (Towards a Long Baseline Neutrino and Nucleon Decay Experiment with a next-generation 100 kton Liquid Argon TPC detector)

The PAC acknowledges the high scientific merit of a neutrino oscillation experiment with a baseline longer than T2K. The measurements of the mixing angle θ_{13} and a possible CP violation in the lepton sector are of highest significance.

The specific P32 proposal is to set up and test a 250 Liter LAr prototype TPC in a low-energy charged particle beam at J-PARC, preferentially with kaons from the K1.1BR beamline. **The PAC encourages the team to proceed with this development work and recommends the allocation of beam time of a low intensity charged particle beam at J-PARC for this test.**

KEK's immediate step toward LAr !

Conclusion

In FY2010-first half of 2011

- T2K may have their first physics results
- Many preparations are on-going at slow extracted beam facility

Further improvements on

- Accelerator power (improvement of beam loss)
- Spill structure of slow extraction
- Increase of operating days/month are eagerly waited

R&D for future possibilities

- Improvement toward multi-MW class accelerator
- New type of neutrino detector
- New technologies in beam (muon sources, UCN etc.)