J-PARC (Particle) Physics Recent Progress

1. Commissioning of accelerator and beam line
2. T2K (neutrino oscillation exp.)
3. $K^0 \rightarrow \pi^0 \nu\nu$ CP violation study
4. Muon physics g-2, μe conversion search
5. Accelerator status and plan

May 21, 2009@FJPPL'09

Koichiro Nishikawa

KEK

KEK Roadmap
2009-2013

Energy Frontier

ILC R&D | Construction | Experiment

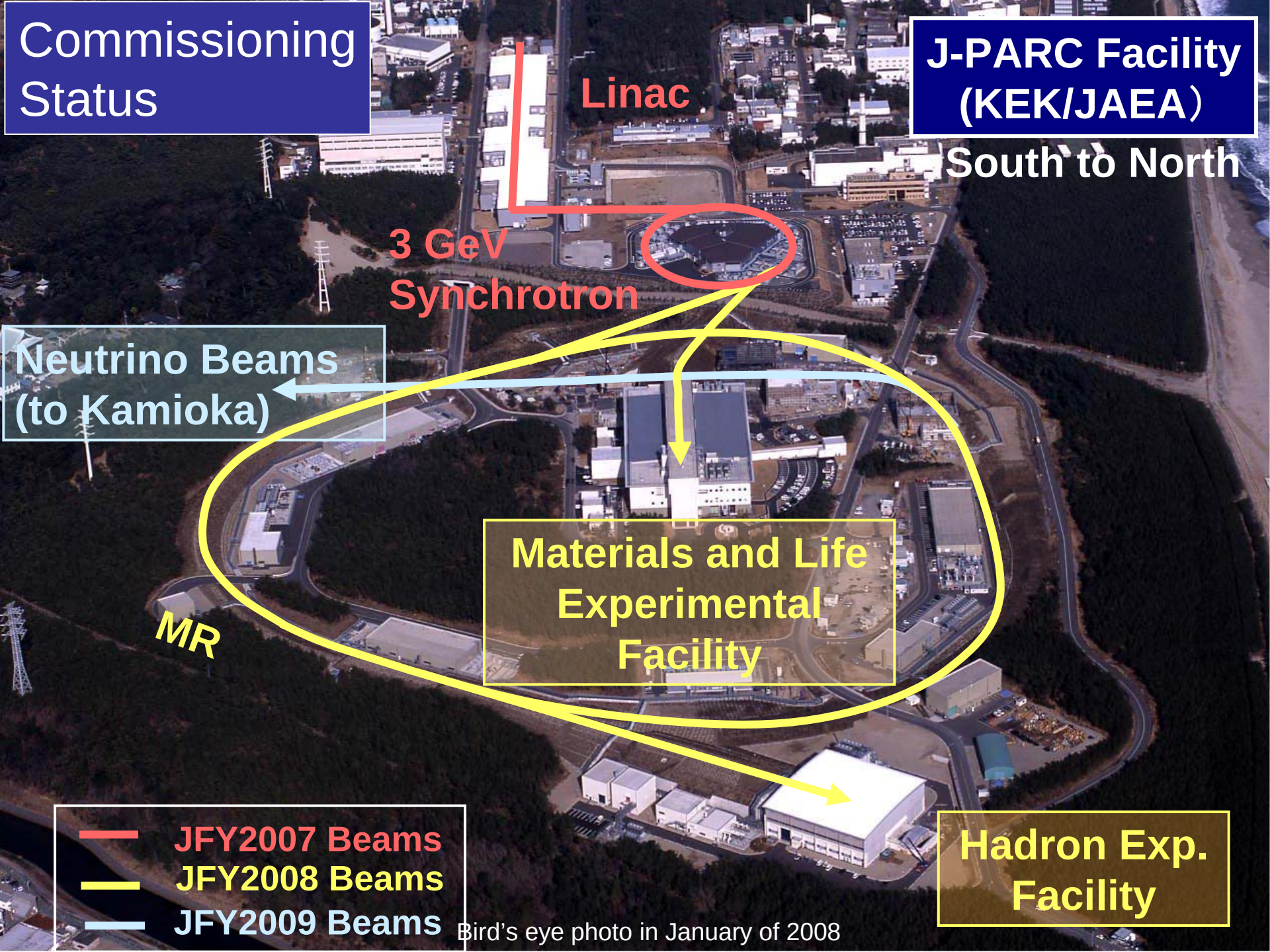
LHC

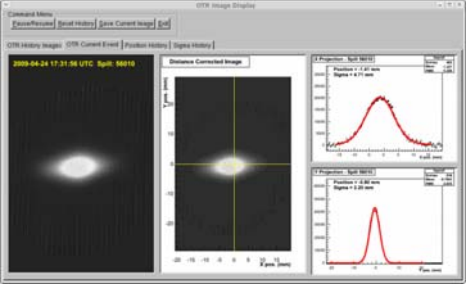
Flavor Physics at Luminosity/Intensity Frontier

ν, K, μ,... at J-PARC

b, c, τ,... with upgraded- KEKB/Belle

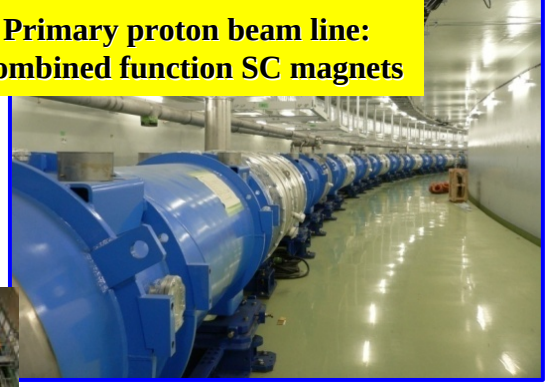
- According to the JAHEP community's master plan,
  - Highest priority is given to ILC
  - Before ILC, promote flavor physics at KEKB and J-PARC
- Action before the ILC approval
  - ILC R&D
  - Completion/commissioning of J-PARC
    - Considering the world competition, it is urgent to improve neutrino intensity
  - Continuation of KEKB/Belle with upgrade

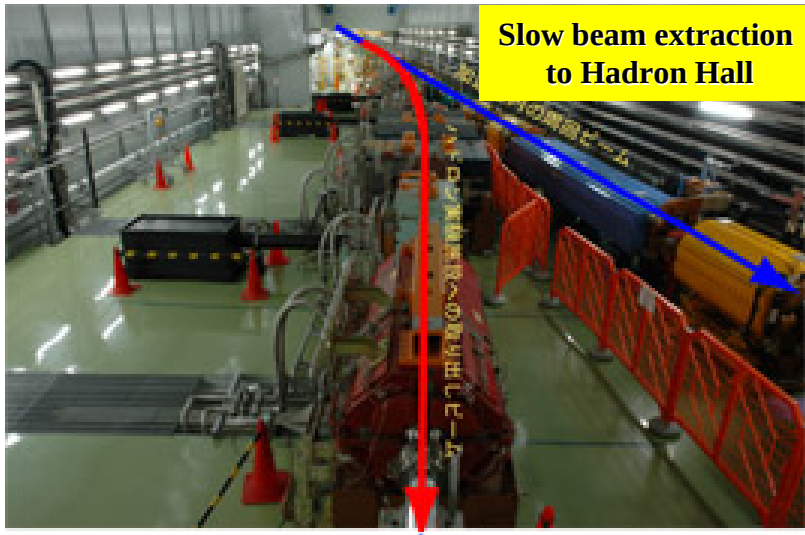

Commissioning Status
J-PARC Facility (KEK/JAEA)
South to North
Linac
3 GeV Synchrotron
Neutrino Beams (to Kamioka)
Materials and Life Experimental Facility
MR
Hadron Exp. Facility
JFY2007 Beams
JFY2008 Beams
JFY2009 Beams
Bird's eye photo in January of 2008



fluorescence plate just in front of target

Primary proton beam line: combined function SC magnets





Slow beam extraction to Hadron Hall

Target station

Graphite target

Recent important milestones:

- ➢December 23, 2008:
  - ❖30 GeV beam acceleration and fast extraction to the beam abort dump
  - ❖MLF user run (20kW)
- ➢January 27, 2009:
  - ❖30 GeV beam extraction to the Hadron Experimental hall using slow beam extraction system
- ➢February 19, 2009:
  - ❖ Government inspection for radiation safety (Hadron hall)
- ➢April 23, 2009:
  - ❖30 GeV beam extraction to the neutrino target station using fast beam extraction system

T2K Collaboration

~ 400 members from 12 Countries

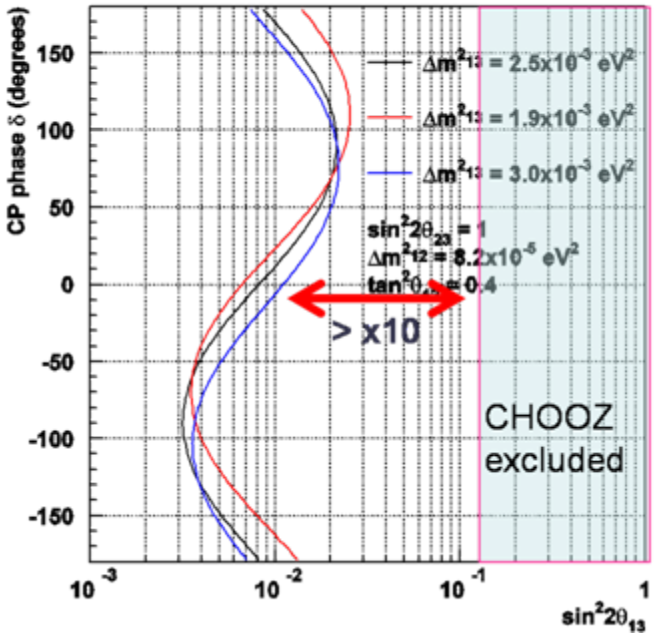
Japan, US, Canada, France, UK, Switzerland, Poland, Korea, Russia, Spain, Italy, Germany

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

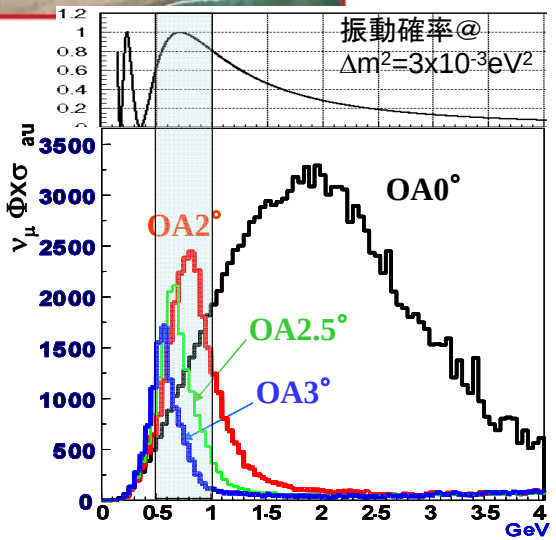
Super-Kamiokande
(ICRR, Univ. Tokyo)

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

ν_e appearance (θ_{13})



- Goal
  - **Discover νe app.**
  - νμ disapp. precision meas.
- Intense narrow spectrum νμ beam from J-PARC MR
  - Off-axis w/ 2~2.5deg
  - Tuned at osci. max.
- SK: largest, high PID performance



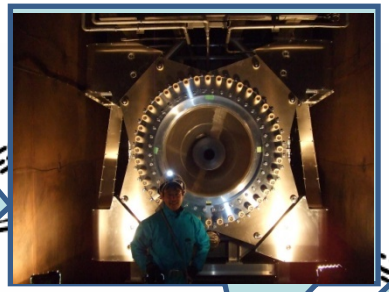
1600ν_μCC/yr/22.5kt (2.5deg)

Neutrino beamline

- **5 year construction 2004~2009**
- **Construction completed on schedule!**

Neutrino monitor build.

Electromagnetic horn

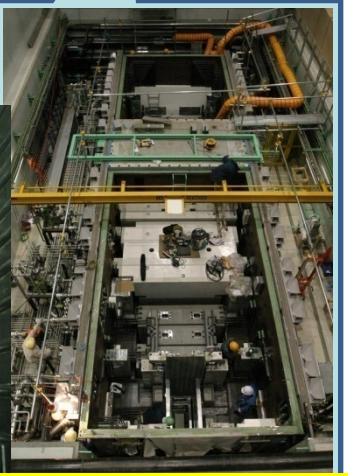


Graphite target

UA1 magnet donated from CERN installed in Apr-Jun, 2008 on schedule

Beam dump completed

Decay volume completed



Target station completed

Primary proton beam line completed

Superconducting Magnet System

- Installation Completed In Dec. 2008
- Cool Down started Jan 2009
- Excitation Test started Feb 2009

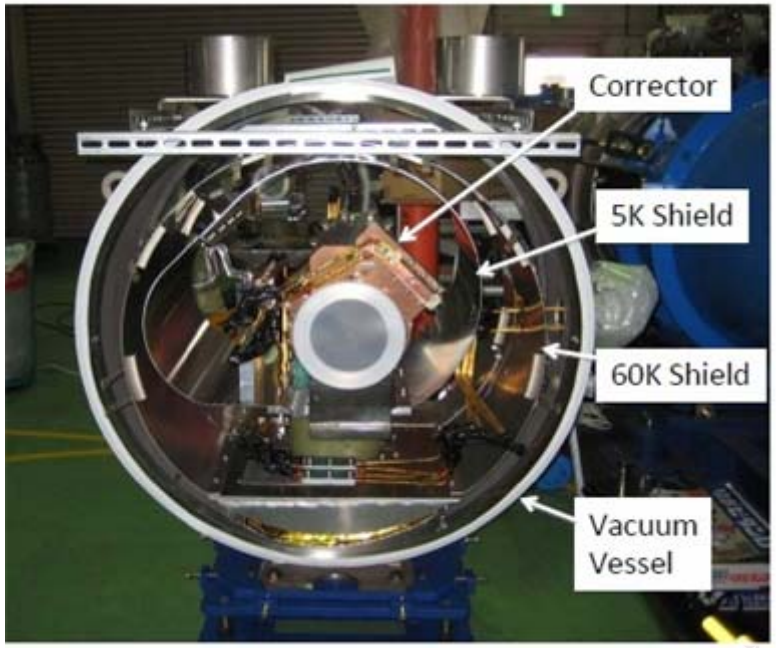
- 4400A (30GeV nominal)
  - quench tests for all the magnets
  - 48 hour excitation test
- 5000A excitation test
  - after full magnet quench
- Main SC Magnet performance
  - OK for spring beam test

Superconducting magnets (II)

- Magnet safety system (MSS) (Saclay)
  - Instllation completed on schedule
  - Commissioning successfully completed
  - Working very well!
- Corrector coils (BNL, US)
  - 3 SC Corrector magnets made by BNL installed

MSS (from Saclay)

Assembled Corrector Inter-Connect (from BNL)

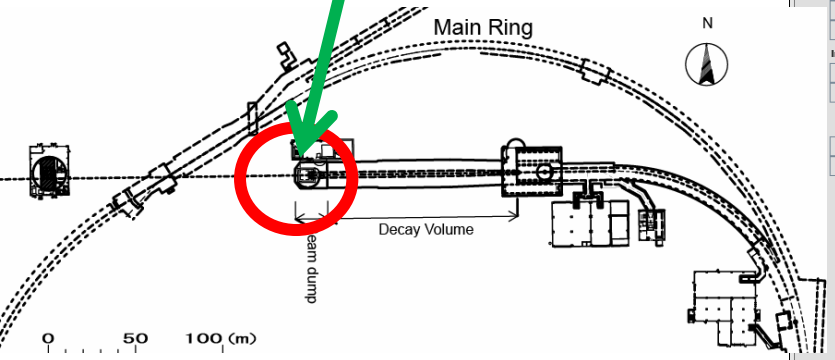


T2K beamline started operation!

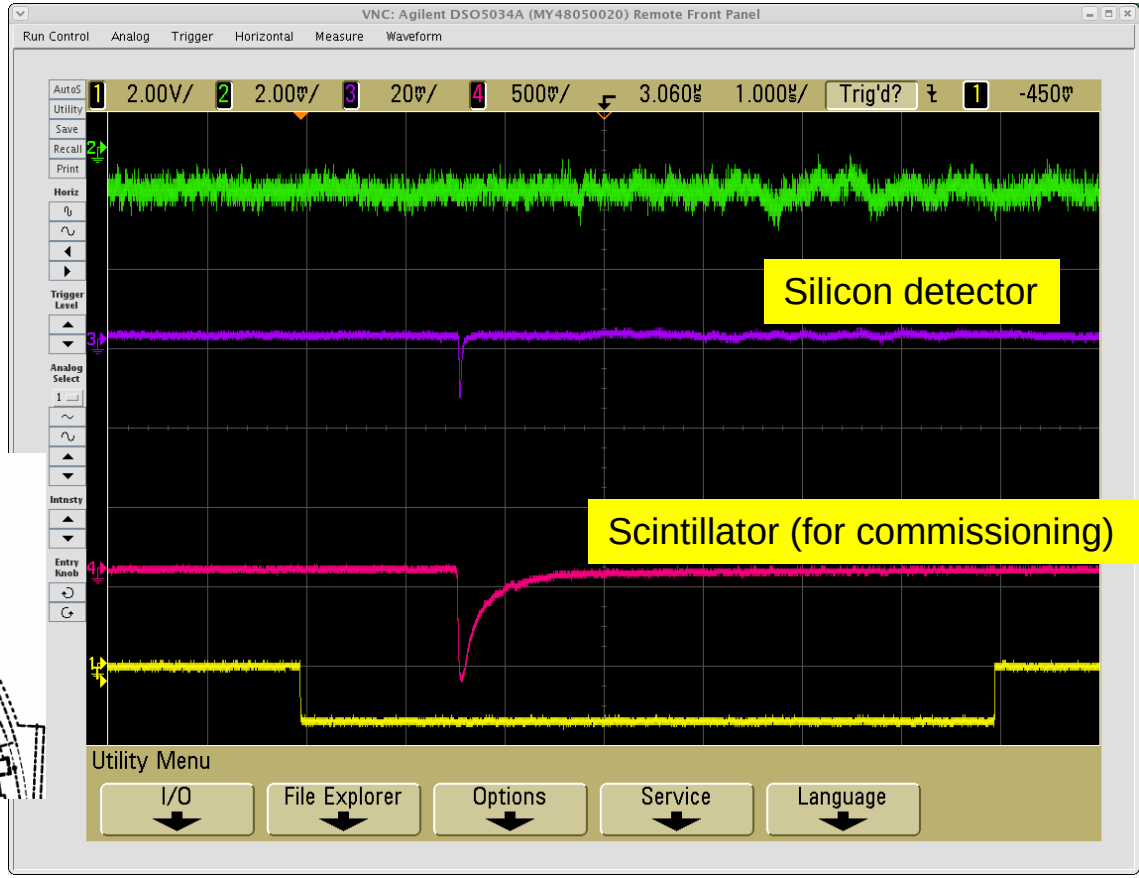
First shot after turning on SC magnets at 19:09, Apr.23, 2009

Muon monitors
(installed behind beam dump)

Ionization Chambers Silicon detectors



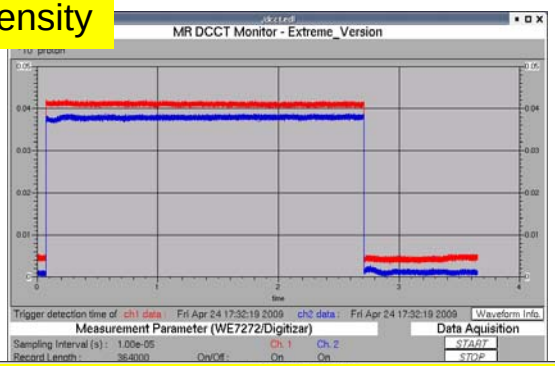
Muon monitor signal



First observation of muons produced in neutrino beamline

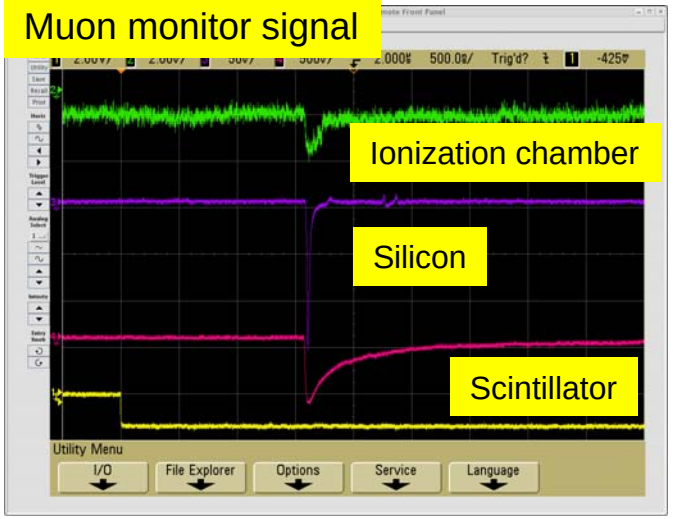
T2K beamline started operation!

MR intensity

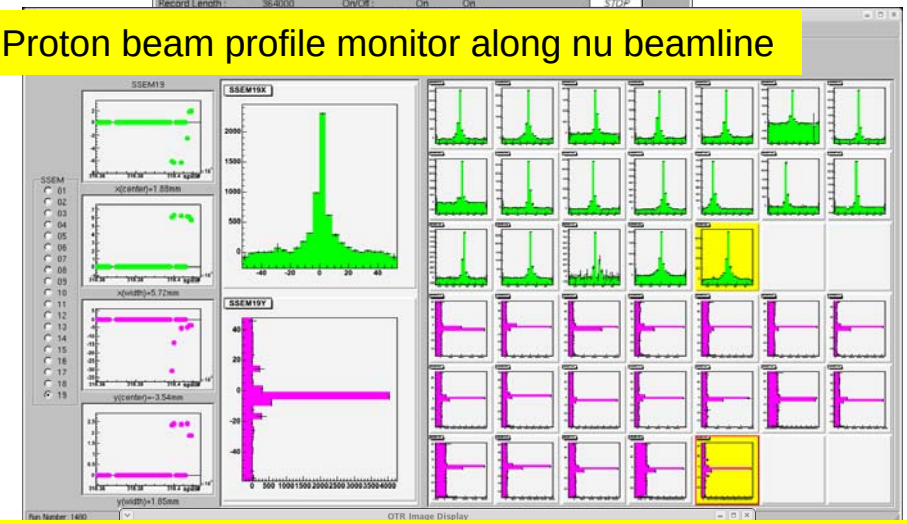


After ~10 shots for tuning, proton beam hit around target center

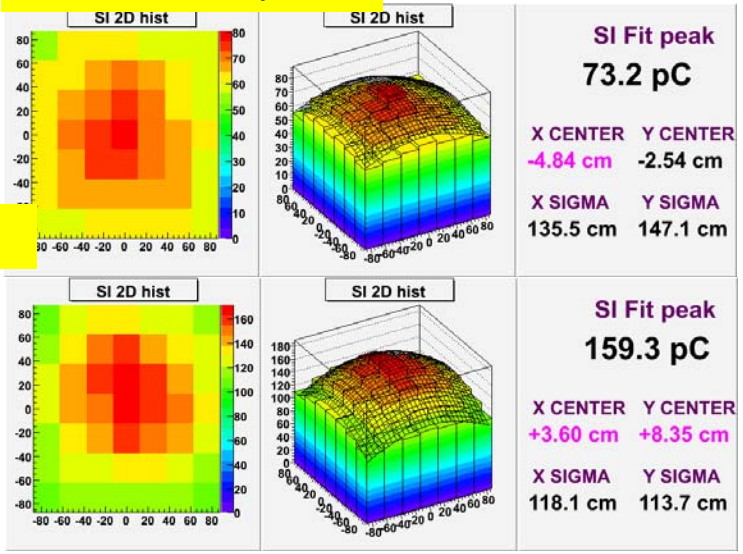
Muon monitor signal



Proton beam profile monitor along nu beamline



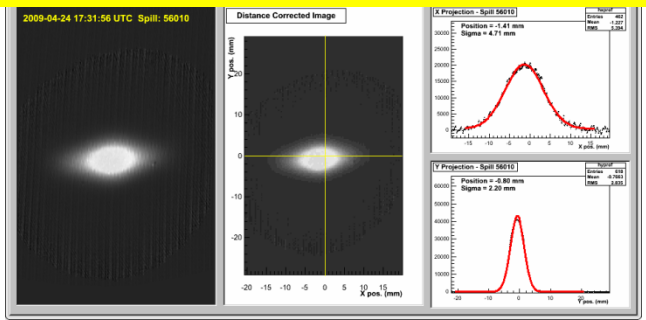
Muon monitor profile



Horn Off

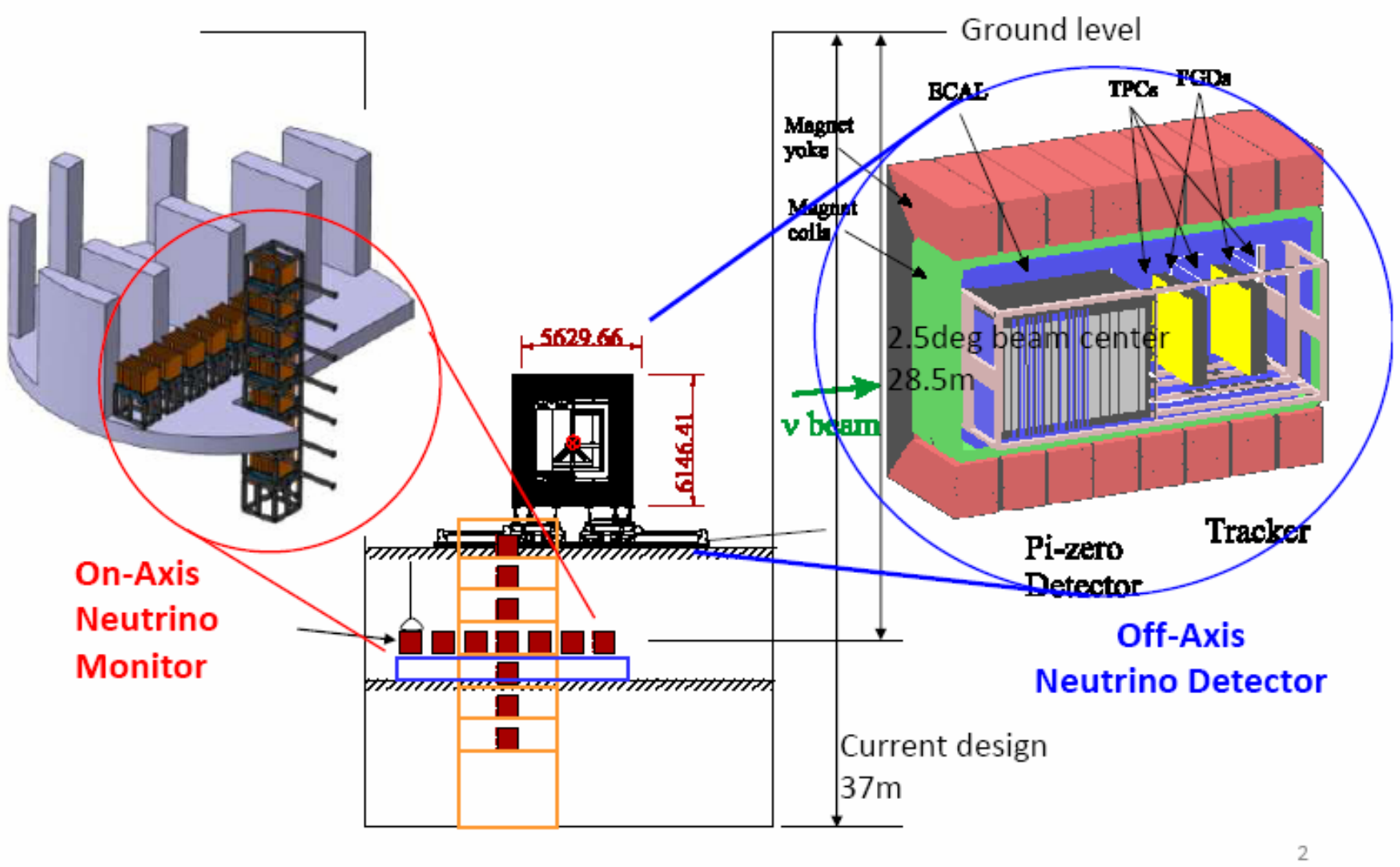
Horn 250kA

OTR detector just in front of target (fluorescence plate)



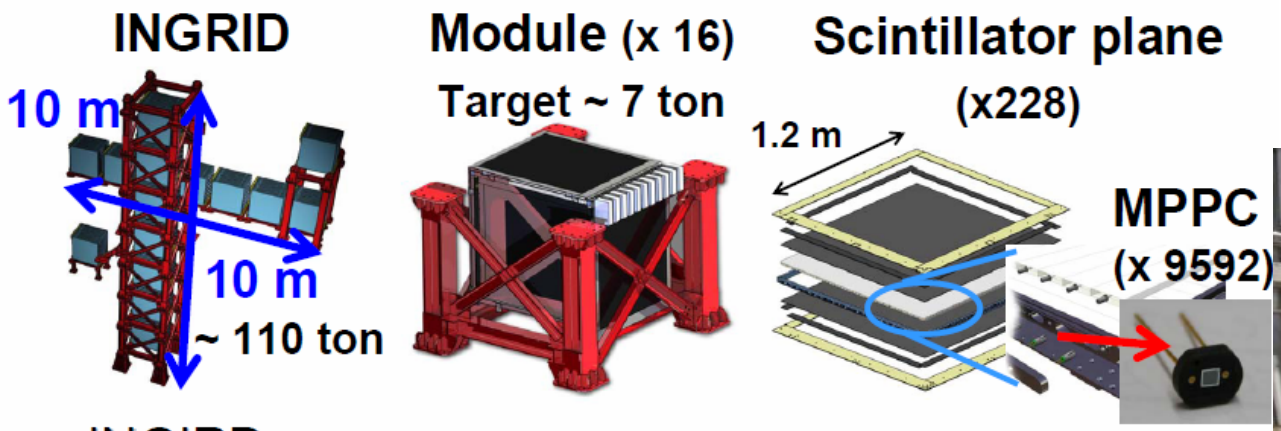
T2K beamline started operation!

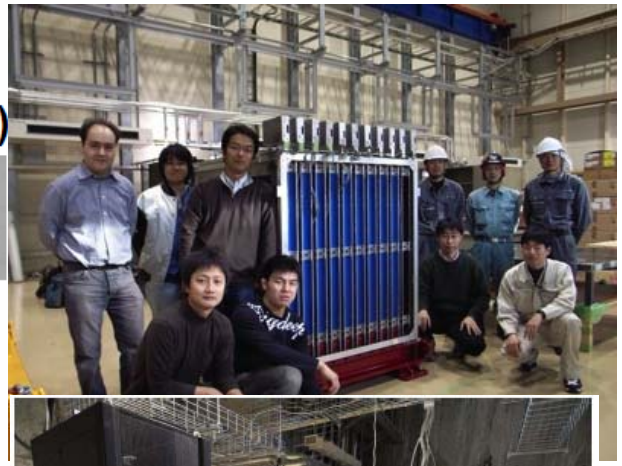
280m Near detectors : being installed



On-axis detector: INGRID

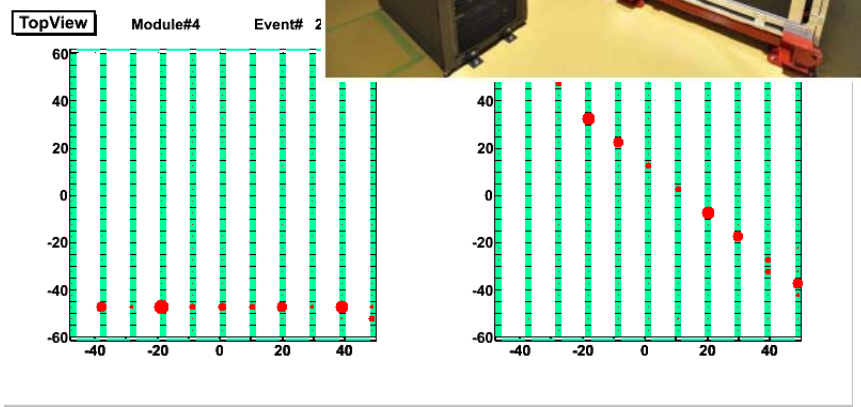
LLR/Ecole Polytechnique
IPNL/LYON
Kyoto University
Osaka University





- INGIRD : 7 (Hori.) + 7 (Vert.) + 2 (Off-axis) modules
- Module : 9 Iron targets + 11 Scinti. planes + Veto planes
- Scintillator plane : 24 ch x 2 layers
  - Scintillator + WLS Fiber + MPPC

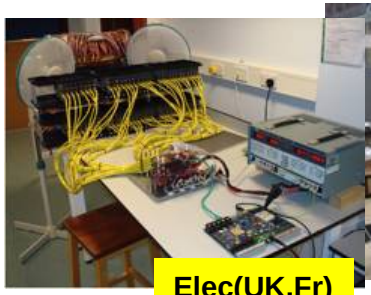
- Assembly of all 228 tracking planes completed
- First module completed and installed. Ready for beam
- Remaining 15 modules will be installed in summer

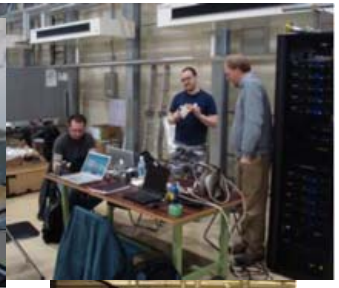


Off-axis Detectors

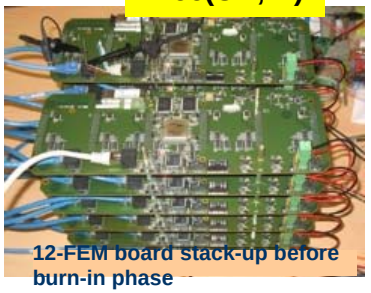
FGD(Canada)

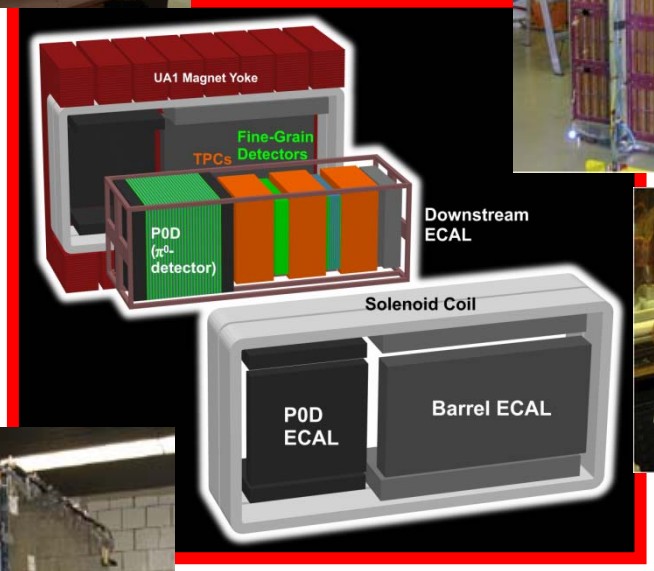
TPC(Canada/Fr)

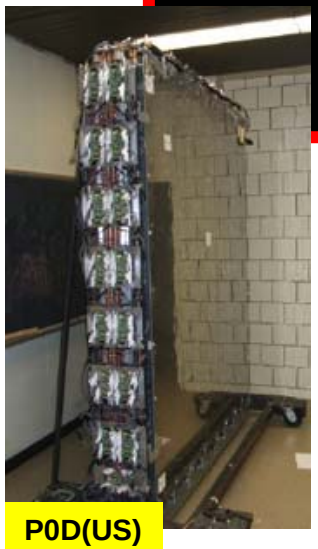




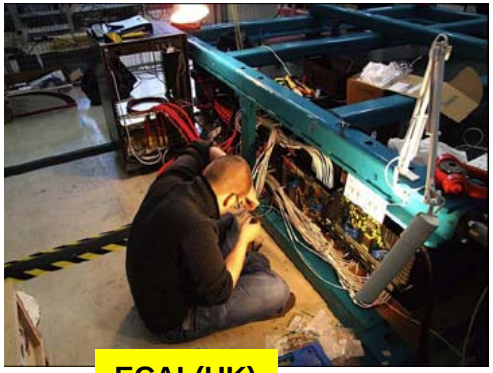
Elec(UK,Fr)







P0D(US)



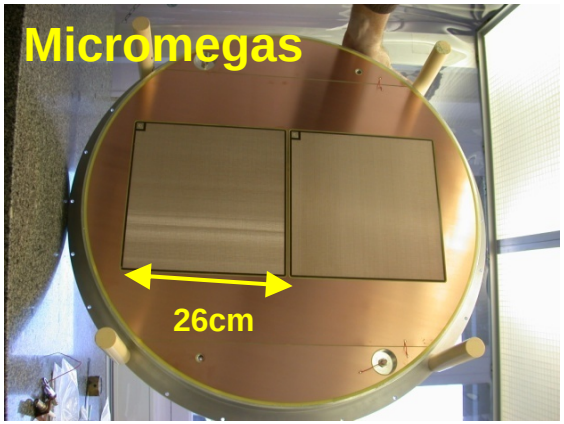
ECAL(UK)

SMRD(Jp,US,Pol,Rus)

- Under construction and testing in each country
- Installation after August
- To be ready for the beam from Winter

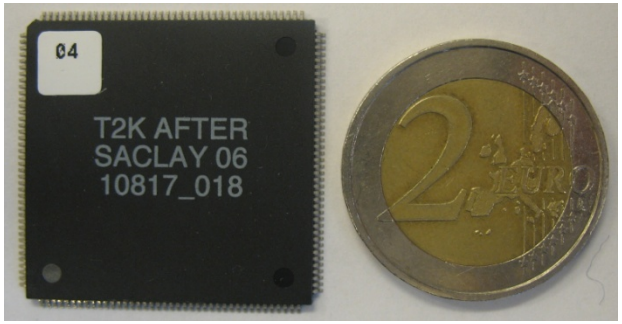
TPC w/ Micromegas

- TPC#0 is equipped with 24 (full) micromegas modules.
- Construction of TPC#1 / #2 going well.



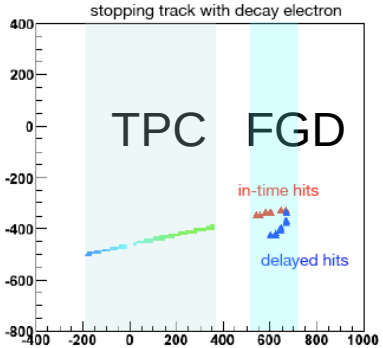
Saclay

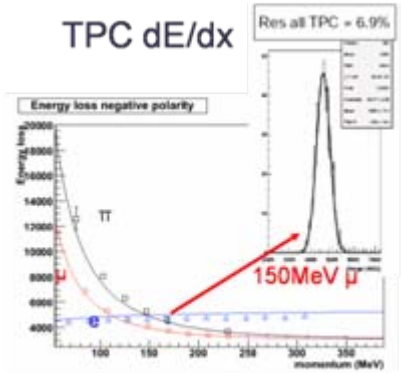
ASIC IC for TPC/FGD



Saclay

Beam test @ TRIUMF





>5σ separation of e/μ for p>200MeV

KOTO
K^0 CP violation experiment

Rare Kaon Decay $K_L^0 \to \pi^0 \nu\bar{\nu}$

BR

10^{-5}

10^{-6}

10^{-7} KEK E391a Run2

10^{-8}

10^{-9} New Physics

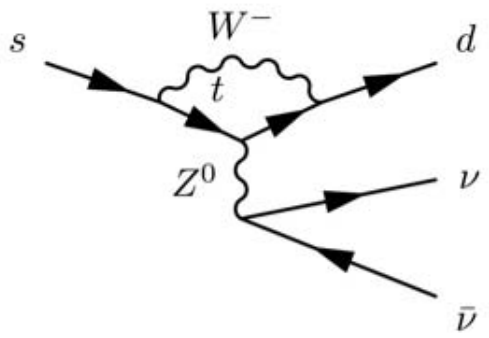
10^{-10}

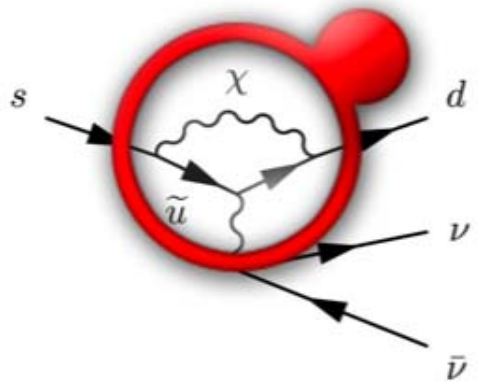
10^{-11} SM, Step 1

10^{-12}

10^{-13} Step 2

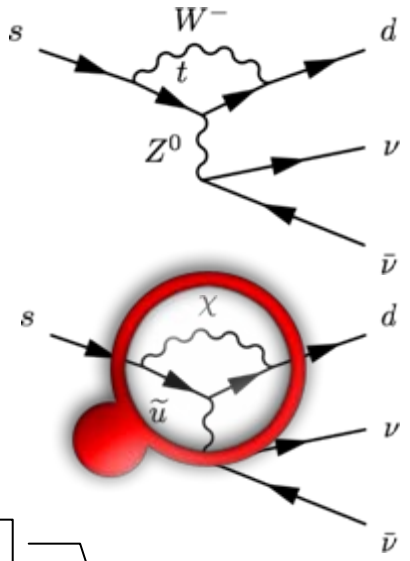
- direct CP-violating rare decay for Physics beyond the Standard Model





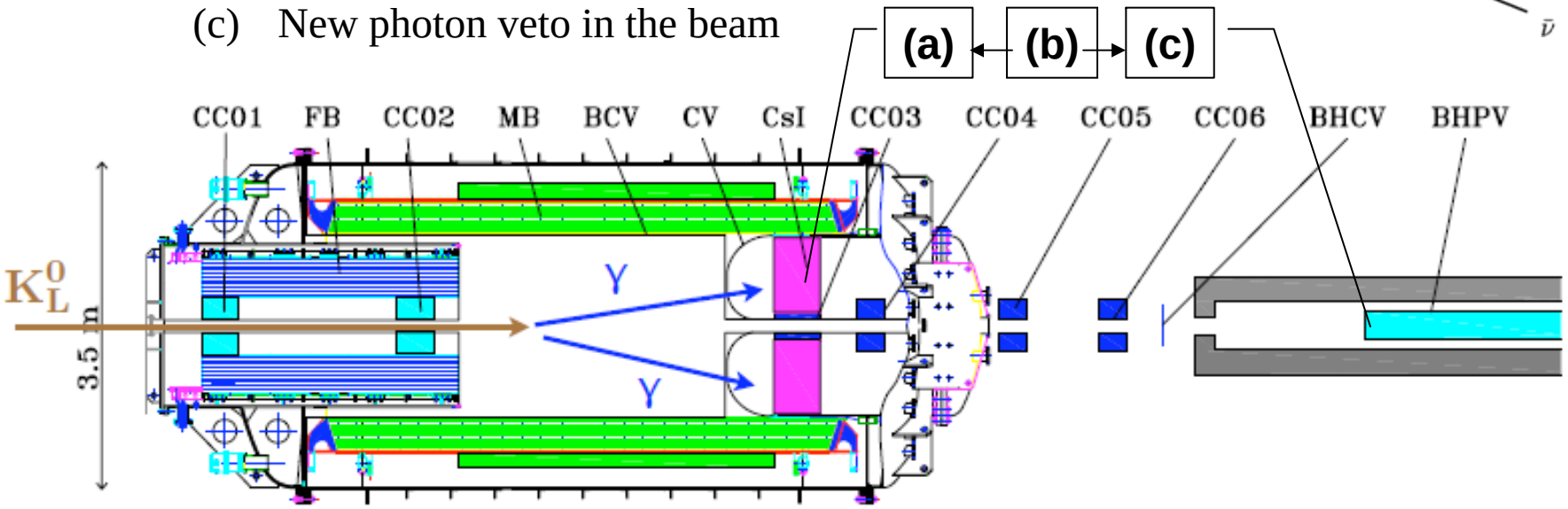
- NA62 at CERN-SPS for $K^+ \to \pi^+ \nu\bar{\nu}$

Beam line is being constructed
Beam survey in 2009



J-PARC ***KOTO*** experiment (K0 at Tokai)

- To study physics beyond SM by measuring branching ratio of $K_L \rightarrow \pi^0 \nu\nu$
- Modify KEK-E391a detector
  - (a) Upgraded CsI calorimeter
  - (b) Readout: waveform digitization
  - (c) New photon veto in the beam



Muon programs
g-2, μe conversion

New Generation of Muon g-2@J-PARC

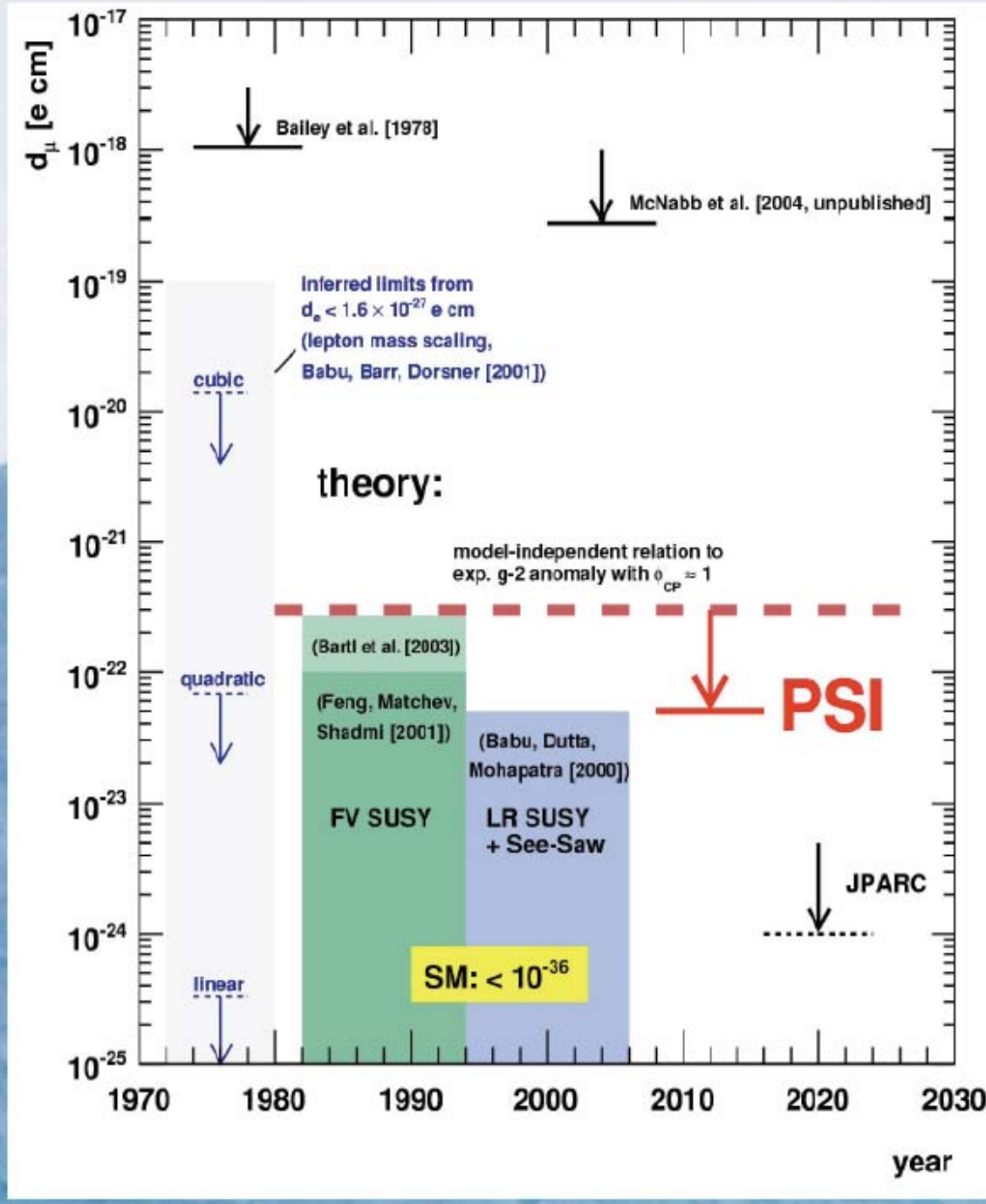
Proposal in preparation

- **Current result is 3.4 sigma above from the SM value**
- **New generation of muon g-2 experiment is being explored at J-PARC**
  - **To establish the deviation by improving the statistics and systematics**
  - **To further explore new physics**
- **With completely new technique**
  - **Off magic momentum with ultra-cold muon beam at 300 MeV/c**
  - **Stored in ultra-precision B field without E-field so that the β x E term drops**

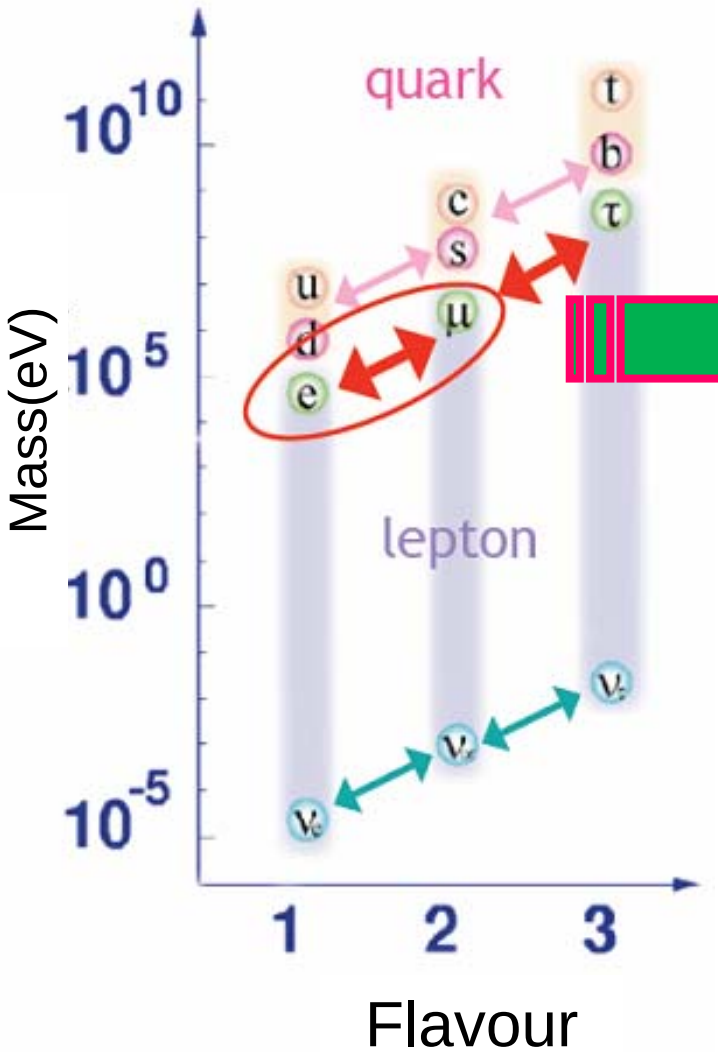
H. Okada

Muon EDM

- Direct CPV in Lepton Sector
- Current Exp. Limit ~ 1e-19
- Potential Sensitivity of J-PARC
  - ~ 1e-22 @ MLF
  - ~ 1e-24 w/ PRISM



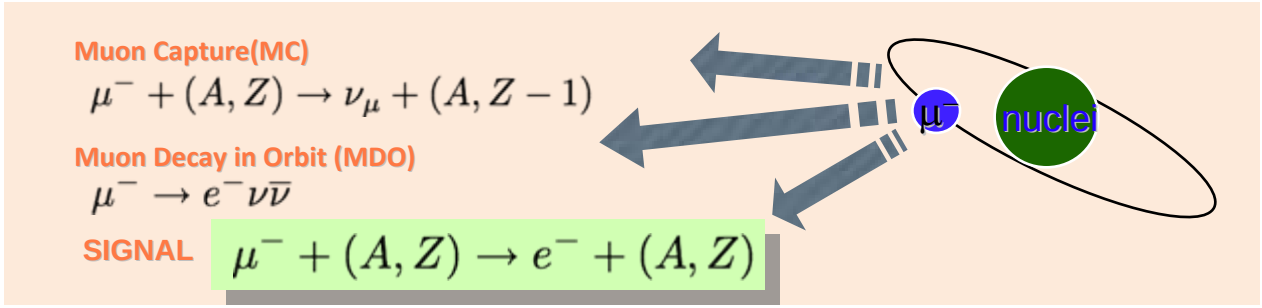
cLFV Search using high-intensity pulsed muon beam

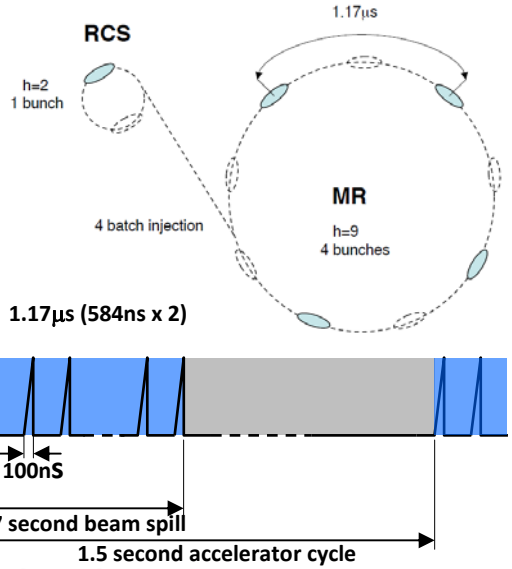


- Quark mixing
  - Precision meas. at B Factories
- Mixture in charged lepton sector
  - Investigation at J-PARC
  - Most sensitive in μ → e
  - Motivated by GUT and Seesaw
- Mixture in neutral lepton sector – Neutrino Oscillation
  - SuperK etc.
  - Precision meas. at K2K, T2K

COMET at J-PARC

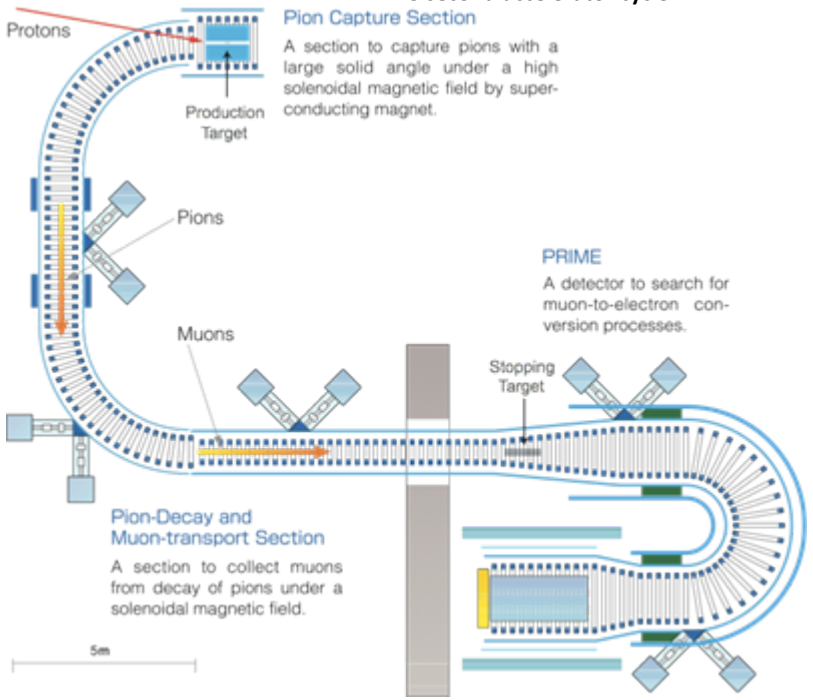
- mu-e conversion search experiment at J-PARC
- Target sensitivity ~**10^{-16}** (*current limit 7×10^{-13} by SINDRUM II*)
- SUSY-GUT models predict $<10^{-13}$





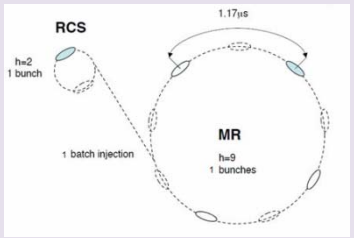
Requirements

- Pulsed Proton Beam
  - π-b.g. suppression
- Large μ yields
  - J-PARC/MR 50-60kW
  - π-capture SC-solenoid
  - 10^{11} μ/sec (cf. 10^{8}μ/sec at PSI PiE5)
- Curved-solenoid detector
  - Lower detector rate



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

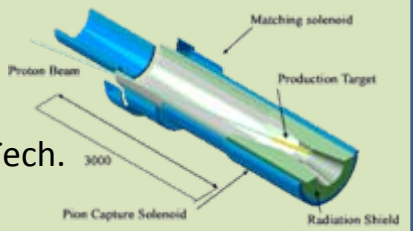
•Detector Solenoid Tech.

•NbTi+Al conductor

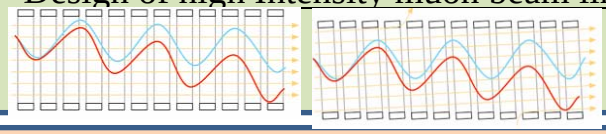
•Indirect pipe cooling

•Conductor development in 2009

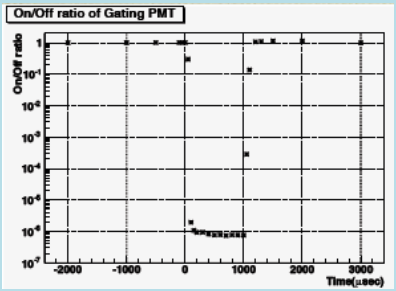
•Test coil construction and test in 2-3 years



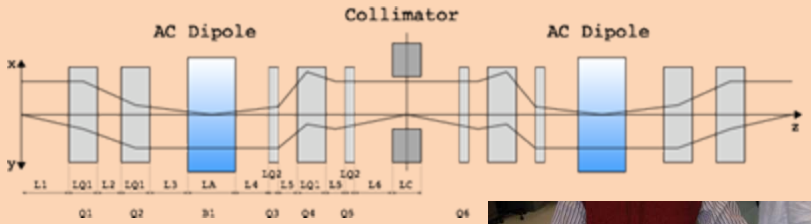
  - Design of high Intensity muon beam line



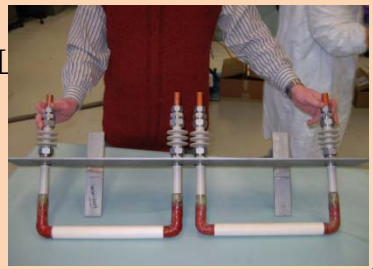
- Extinction monitoring device development
  - Gating PMT for a Gas Cerenkov detector, 1MHz switching with 10^6



- AC-dipole development



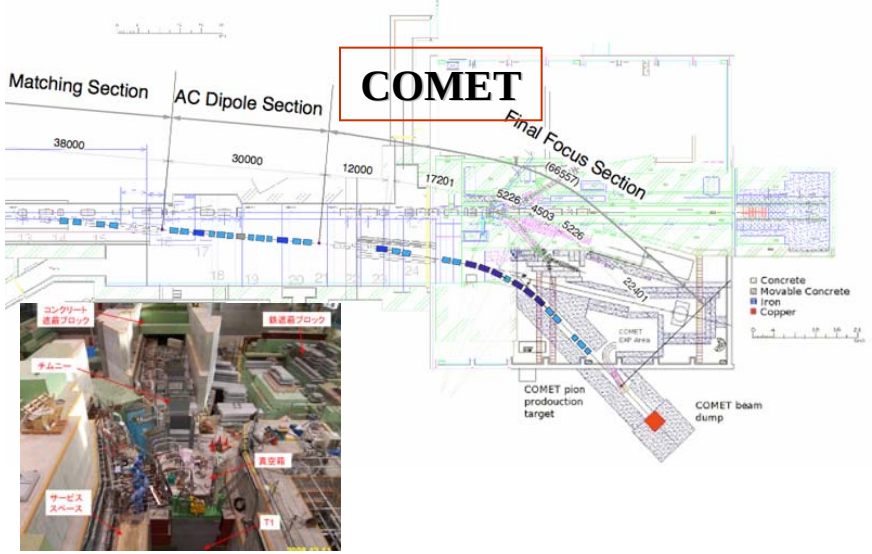
  - Collaboration with FNAL
  - Conductor Development



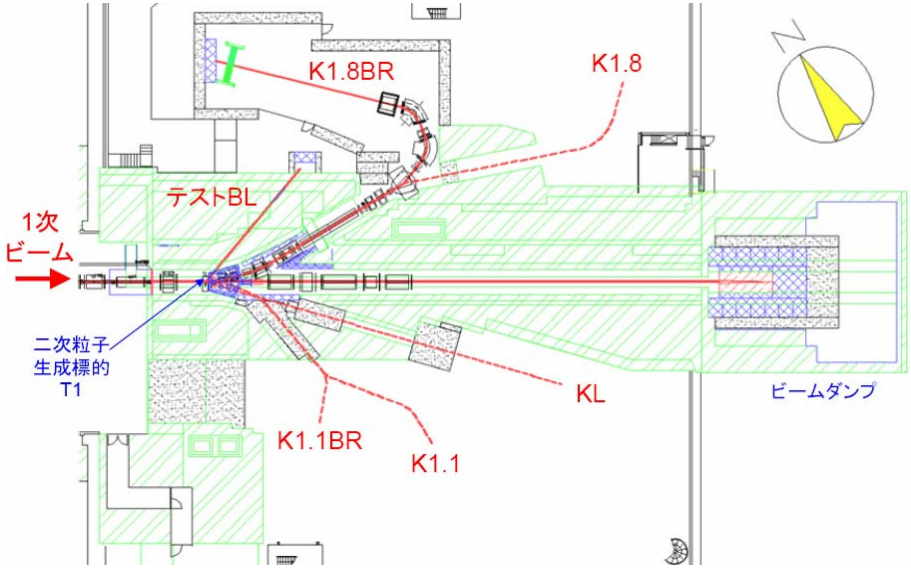
•1st version corona-tested

•2nd version built

•Single brick test soon



A possible layout of the beam lines at Hadron Facility.
K1.8, K1.8BR, and KL are implemented as of July, 2009.



K1.8 (Day-1)
(E05): Spectroscopic study of hypernuclei
(E13): Gamma-ray spectroscopy of light hypernuclei
(E19): Pentaquark search in $\pi p \rightarrow K^- X$
K1.8 (stage-2)
(E03): Measurement of X-rays from Ξ Atom
(E07): Double strangeness system
K1.8BR (Day-1)
(E15): Search for deeply-bound kaonic nuclear states
(E17): Precision spectroscopy of kaonic ^{3}He
K1.1
K1.1BR (stage-1)
(E06): Measurement of T-violation in $K^+ \rightarrow \pi^0 + \mu^+ + \nu$
High-P_T (stage-1)
(E16): Chiral symmetry in QCD
KL (stage-2)
(E14): $K_L \rightarrow \pi^0 + \nu\bar{\nu}$
COMET (New beam line, diferred)
μ-e conversion experiment at sensitivity of 10^{-16}

Accelerator Status and Plan

Beam commissioning has been accomplished on schedule,
BUT with low intensity.
Real challenge toward the power frontier machine just started.

1. Many issues (unreliable components, design etc.) to be solved
2. Beam must be provided to the users
3. Power upgrade should be also accomplished steadily.

- RFQ discharge problem:
- RF core long term stability problem:
- Stability of MR power supply and beam loss

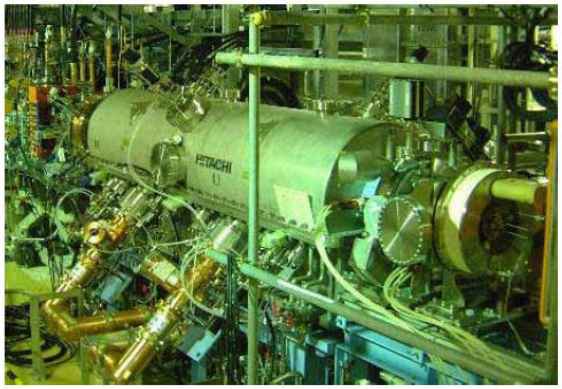
  - No problem for fast extraction with a level of 100kW operation
  - Need more stability for slow extraction

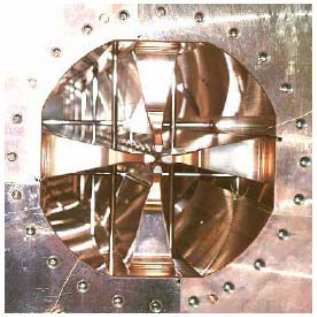
  - Clearly need major improvement for MW operation

Three serious issues which may give impact to the schedule:

1. **Linac: RFQ**
2. **RCS: RF FM core**
3. **MR: Magnet Power Supply**

Discharge problem in the RFQ limits both beam power and availability.

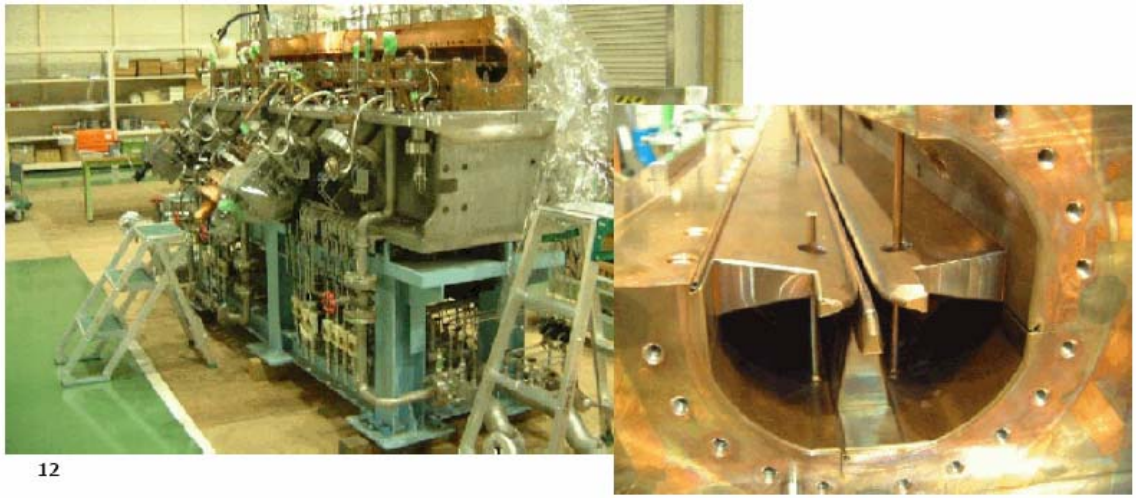




Inside of RFQ

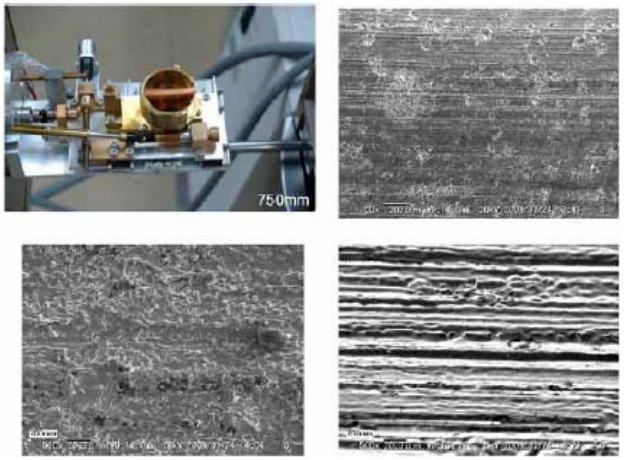
We are earnestly making a backup RFQ, which will be replaced during summer shutdown in 2010

Vacuum vessel of RFQ
Poor vacuum design



Pi mode Stabilizing Loop

Poor surface fabrication method



Three serious issues which may give impact to the schedule:

1. **Linac: RFQ**
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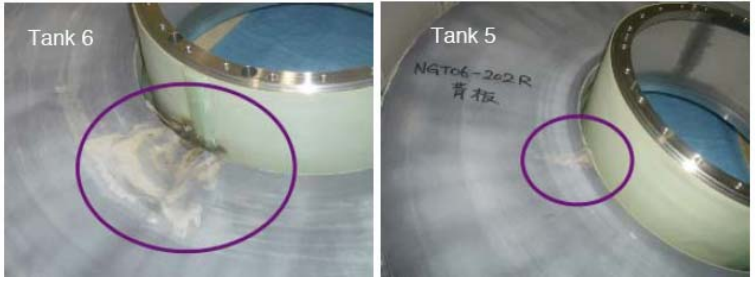
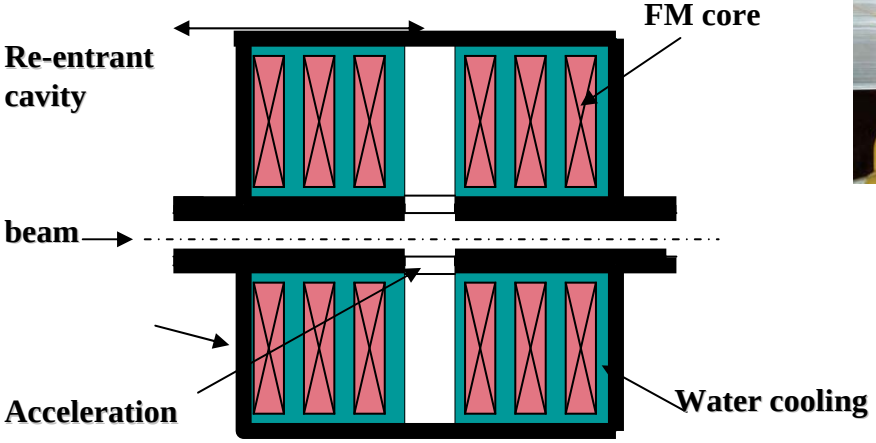


18枚中11枚のコアに損傷が見られた。予備のコア(2)を入れて4月の運転に備える。至急、新規にコアを製作。

Compression buckling due to thermal stress

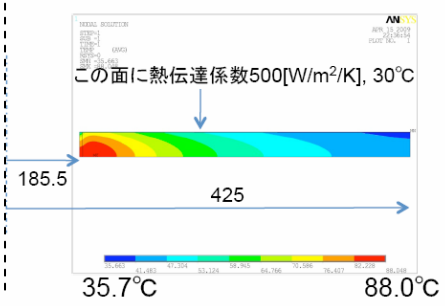


15kV/gap

Discharge problem

Temperature distribution

温度分布



Core center

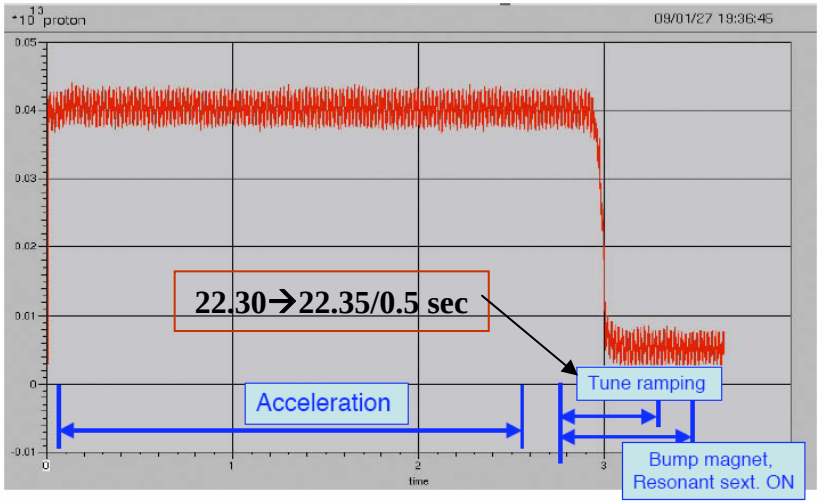
Z-component of stress

Strong thermal stress @ 5kW loss

200 cores are used for RCS cavities
Unit cost: 40k dollar !

Slow extraction operation

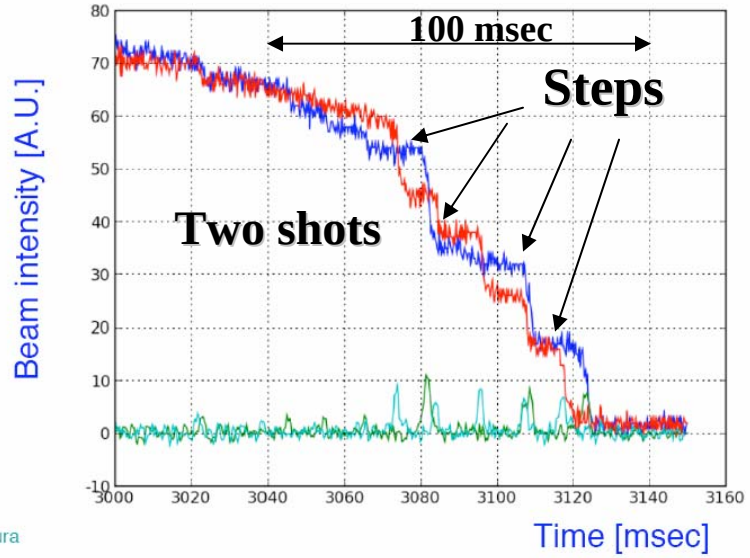
Slow extraction: Bump magnets ON
Resonant sextupoles ON
Tune ramp pattern for QFN: (22.30, 20.78) -> (22.35, 20.78)



Slow extraction tuning and beam loss

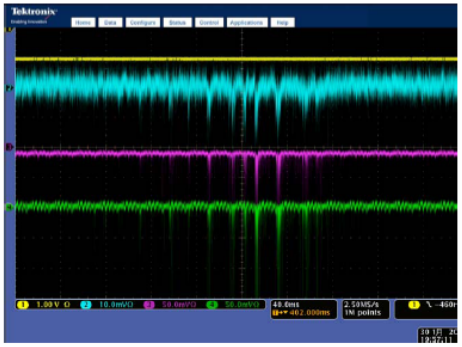
It's a "Ripple extraction" using SX system
We need;
→further improvement of magnet power supply
→installation of feedback system

Beam intensity during extraction

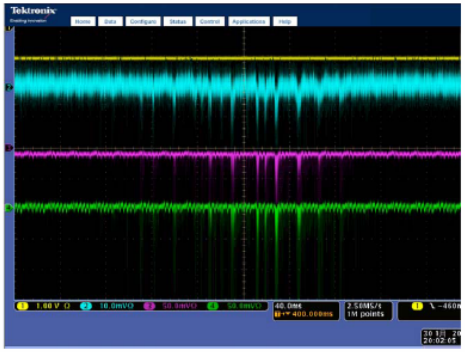


Spill measurement in HD beamline

RF off, ξ~0



RF off, ξ~-2



Summary

Neutrino

1. **Early achievement of 100kW run (for 10^7 sec, in 2010)**
2. **Create strong team to consider and work for the power upgrade scenario from 100 to 750kW.(2011~)**
1. **The above second step should be the base of the MW-class power frontier machine.**

Hadron

1. **Early realization of spill control by;**
   - **improving magnet power supplies, and**
   - **applying feedback system.**
2. **Early achievement of 10kW-class power by;**
   - **understanding and suppressing and/or localizing the beam loss.**
3. **In order to realize 100kW-class slow beam extraction, we have to develop;**
   - **excellent extraction efficiency,**
   - **more beam loss control, and**
   - **radiation maintenance technology.**