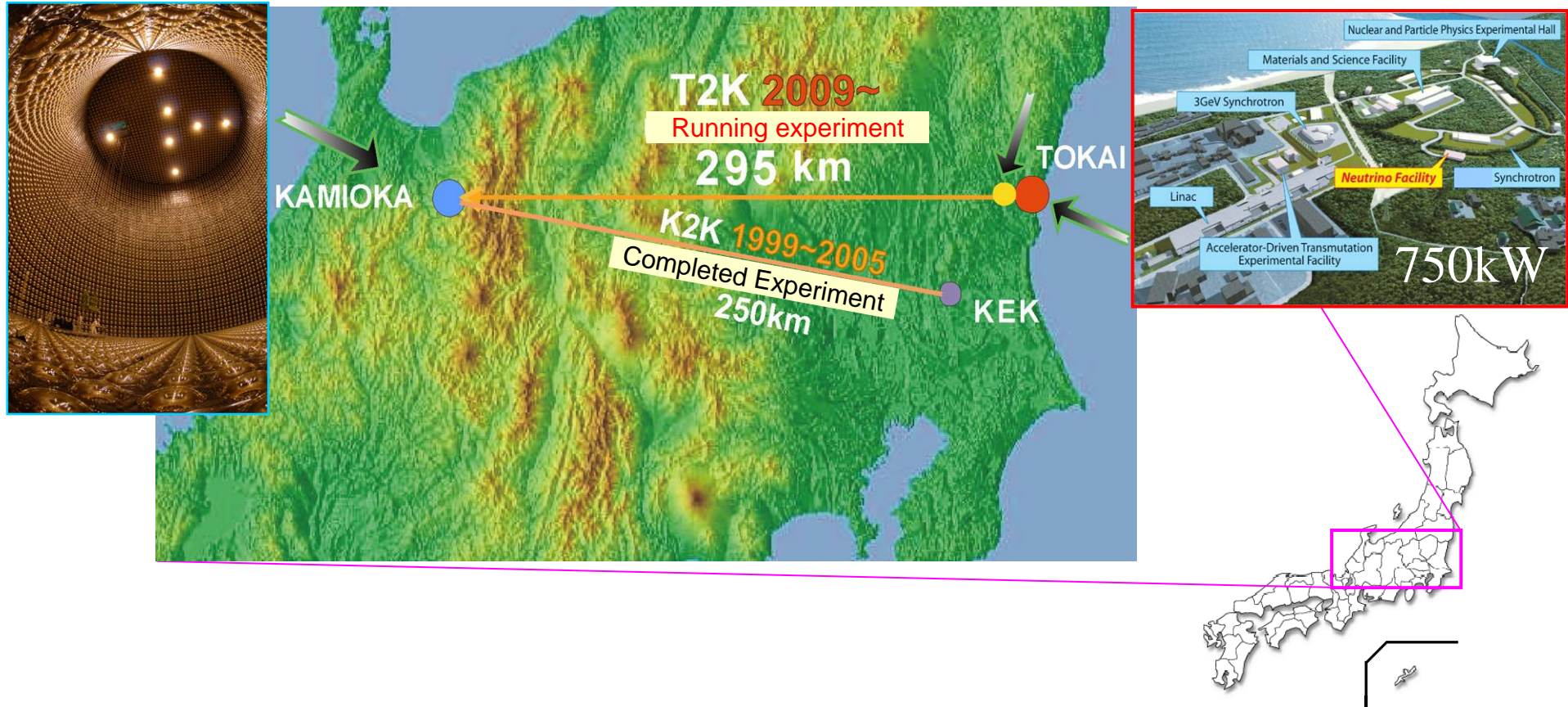


Status J-PARC Neutrino Program: T2K



T. Nakadaira (KEK)
for
T2K collaboration

T2K (Tokai to Kamioka) LBL ν experiment



- Searches for $\nu_{\mu} \rightarrow \nu_e$ oscillation (ν_e appearance)
- Precise measurement of $\nu_{\mu} \rightarrow \nu_{\mu}$ (ν_{μ} disappearance)

T2K Collaboration



- 12 Countries

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

- 62 Institutions, ~500 members.

Outline

- Physics Goal
- Principle of T2K experiment
- Experimental setup & status
 - status in 2009~2010
 - Accelerators
 - Neutrino Beam line
 - Hadron production measurement: *CERN NA61*
 - Near & Far detector
- Summary

Main Physics Goal

- Searches for $\nu_\mu \rightarrow \nu_e$ oscillation (ν_e appearance)

Flavor eigenstate $\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos \theta_{23} & \sin \theta_{23} \\ 0 & -\sin \theta_{23} & \cos \theta_{23} \end{pmatrix} \begin{pmatrix} \cos \theta_{13} & 0 & \sin \theta_{13} e^{-i\delta} \\ 0 & 1 & 0 \\ -\sin \theta_{13} e^{-i\delta} & 0 & \cos \theta_{13} \end{pmatrix} \begin{pmatrix} \cos \theta_{12} & \sin \theta_{12} & 0 \\ -\sin \theta_{12} & \cos \theta_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$ Mass eigenstate

SK Atm., K2K, MINOS
 $\theta_{23} \sim 45^\circ$
 $\Delta m^2_{23} \sim 2.5 \times 10^{-3} [\text{eV}^2]$

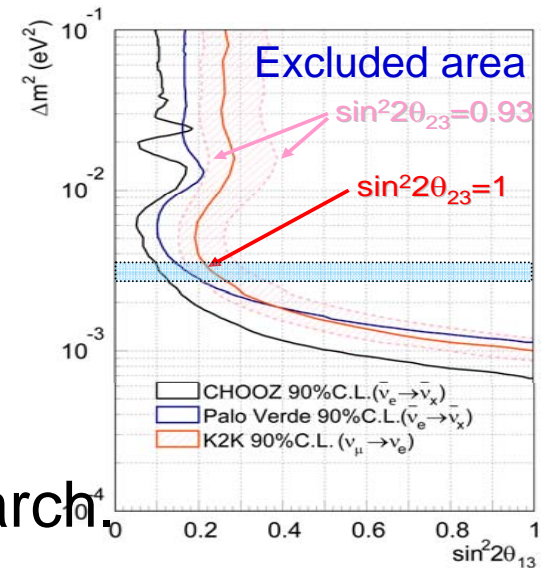
θ_{13}, δ are still unknown.

Solar, KamLAND
 $\theta_{12} \sim 34^\circ$
 $\Delta m^2_{12} \sim 8 \times 10^{-5} [\text{eV}^2]$

$$\theta_{13} \ll \theta_{12}, \theta_{23}$$

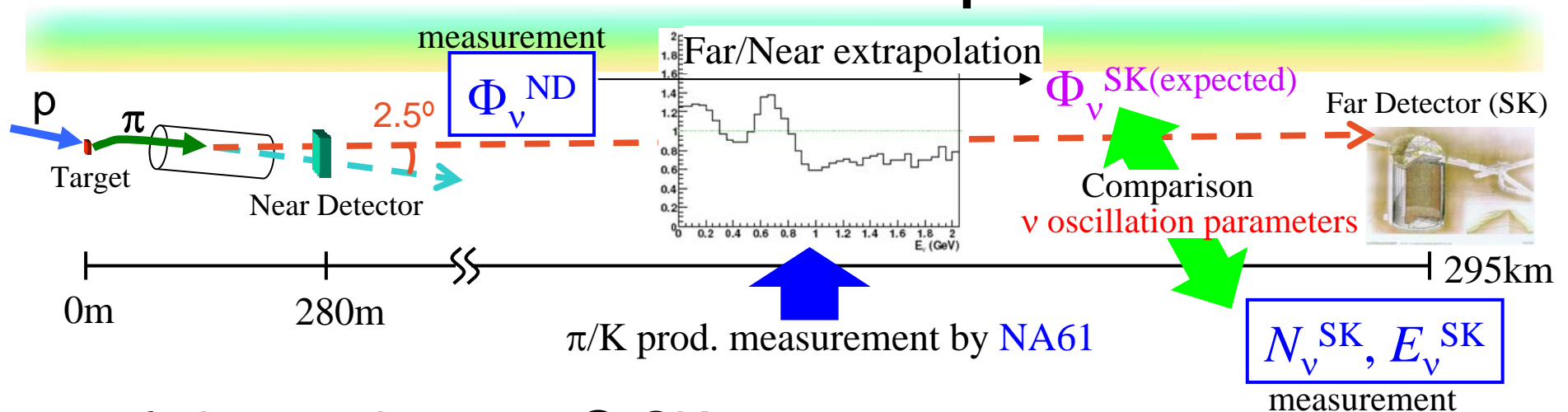
$$P(\nu_\mu \rightarrow \nu_e) \approx \sin^2 2\theta_{13} \sin^2 \theta_{23} \sin^2(\Delta m^2_{31} L / 4E) + \dots$$

\ominus for ν (Approximation @ $\Delta m^2_{31} L / 4E \sim \pi/2, \Delta m^2_{32} \sim \Delta m^2_{31}$)
 \oplus for $\bar{\nu}$ $J_r \equiv \cos \theta_{12} \sin \theta_{12} \cos \theta_{23} \sin \theta_{23} \cos^2 \theta_{13} \sin \theta_{13}$



- Measure the unknown mixing parameter θ_{13}
 \rightarrow Finite θ_{13} lead us to future CP violation search.

T2K concept



- # of observed events @ SK:

$$N_{\nu e}^{\text{SK}} = P(\nu_{\mu} \rightarrow \nu_e) \times \Phi^{\text{SK}}(\nu_{\mu}) \times \sigma(\nu \text{ interaction})$$

- $\Phi^{\text{SK}}(\nu_{\mu}) \times \sigma(\nu \text{ int.}) = R(\text{SK/ND}) \times \Phi^{\text{ND}}(\nu_{\mu}) \times \sigma(\nu \text{ int.})$
 $= R(\text{SK/ND}) \times N_{\nu e}^{\text{ND}} \leftarrow \text{ND measurement.}$

- $R(\text{SK/ND})$: Far to Near flux extrapolation.

- Targeting condition: Measured by proton beam monitors.

- p_{π}, θ_{π} distribution : Measured by CERN NA61

“Beam MC”

- Horn focusing effect, π decay kinematics, geometrical acceptance.

Signal events in T2K: CC-QE

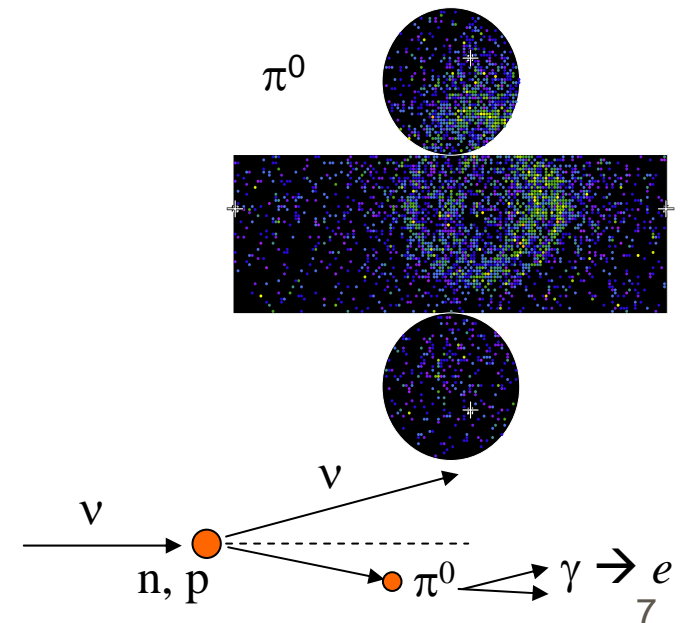
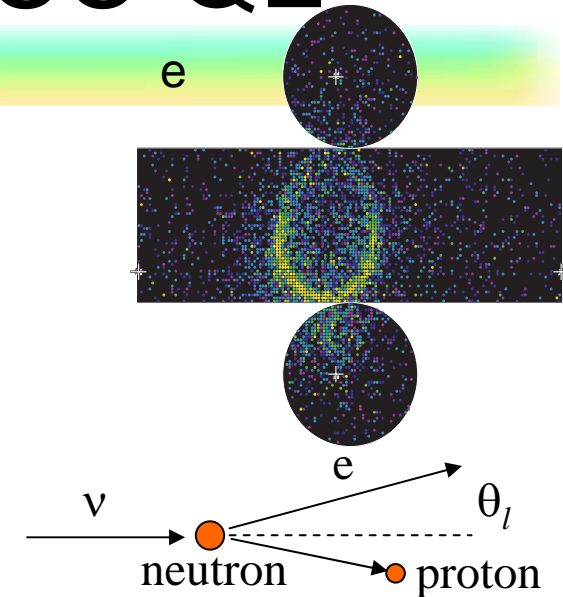
- Charged current quasi-elastic events:

- Dominant interaction
 - @ 1st oscillation maximum. $E_\nu \sim 0.6\text{GeV}$
- Good SK performance
 - e / μ separation
 - Energy reconstruction: $\Delta E/E \sim 10\%$

- Background events

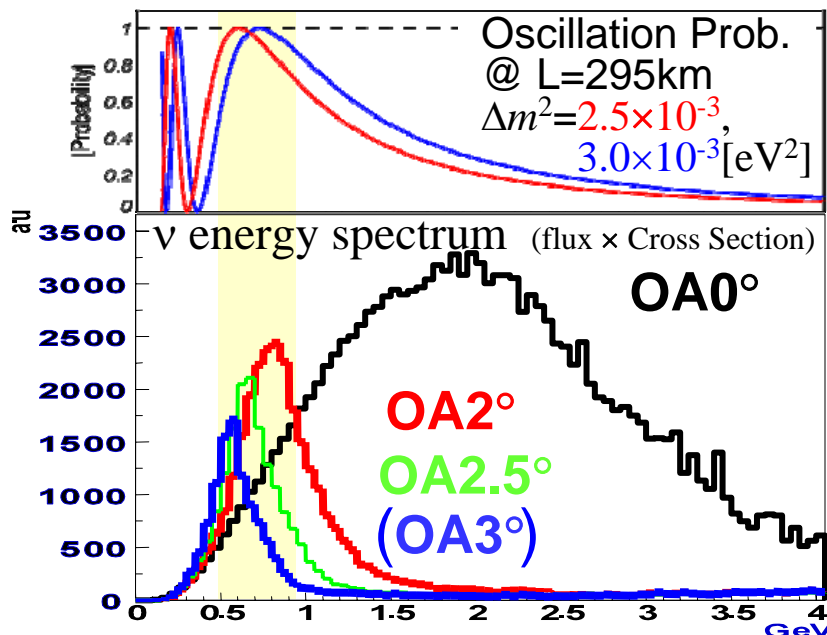
- ν_e appearance search.
 - π^0 from NC events:
 - Intrinsic ν_e contaminated in ν_μ beam
← measured by ND.
- ν_μ disappearance
 - CC-non QE events w/ missing particle
... E_ν reconstruction is not correct.

→ High energy components in ν beam produce the background.

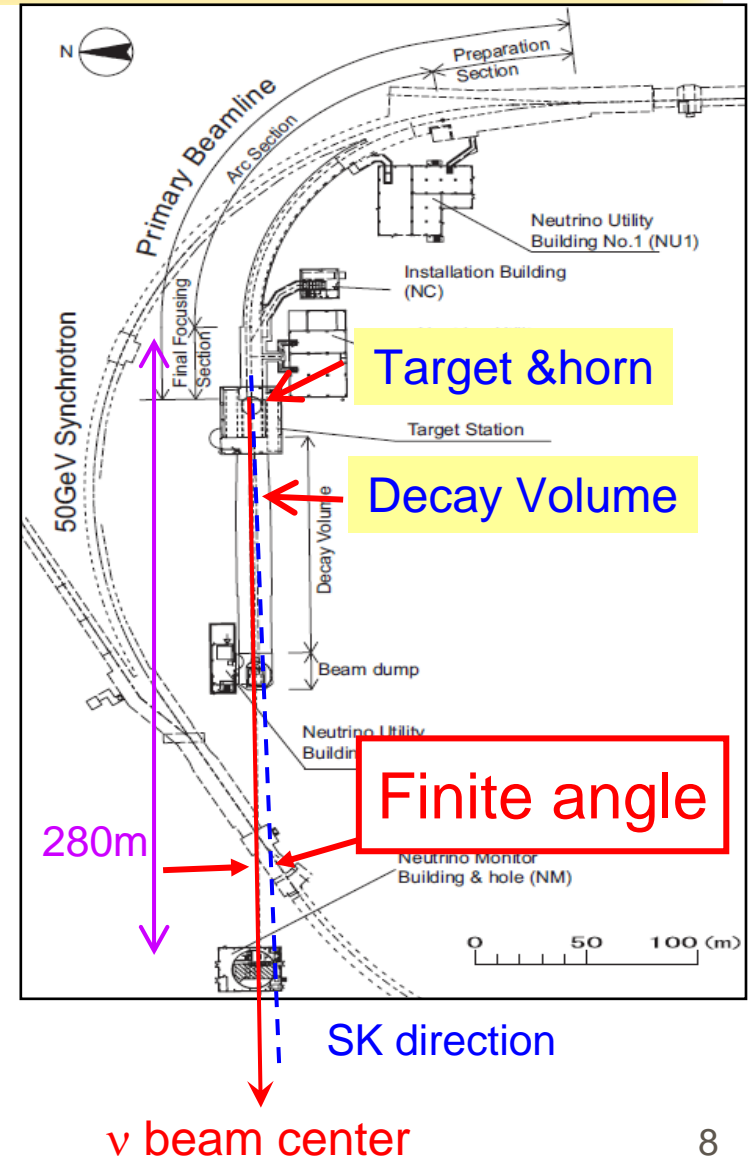


Off-Axis beam

- Pseudo-Monochromatic beam by Off-Axis method (ref. BNL E899)
 - ν_μ beam is produced by conventional method.
 - Focus secondary pions using EM horns.
 - ν_μ is produced from pion decay in flight.
 - ν_μ beam intentionally miss the SK direction.
- Set peak of $(\text{flux} \times \sigma_{\text{CC}})$ @ oscillation max.
 - Fraction of high energy neutrino is small.



OA = 2.5° is selected.



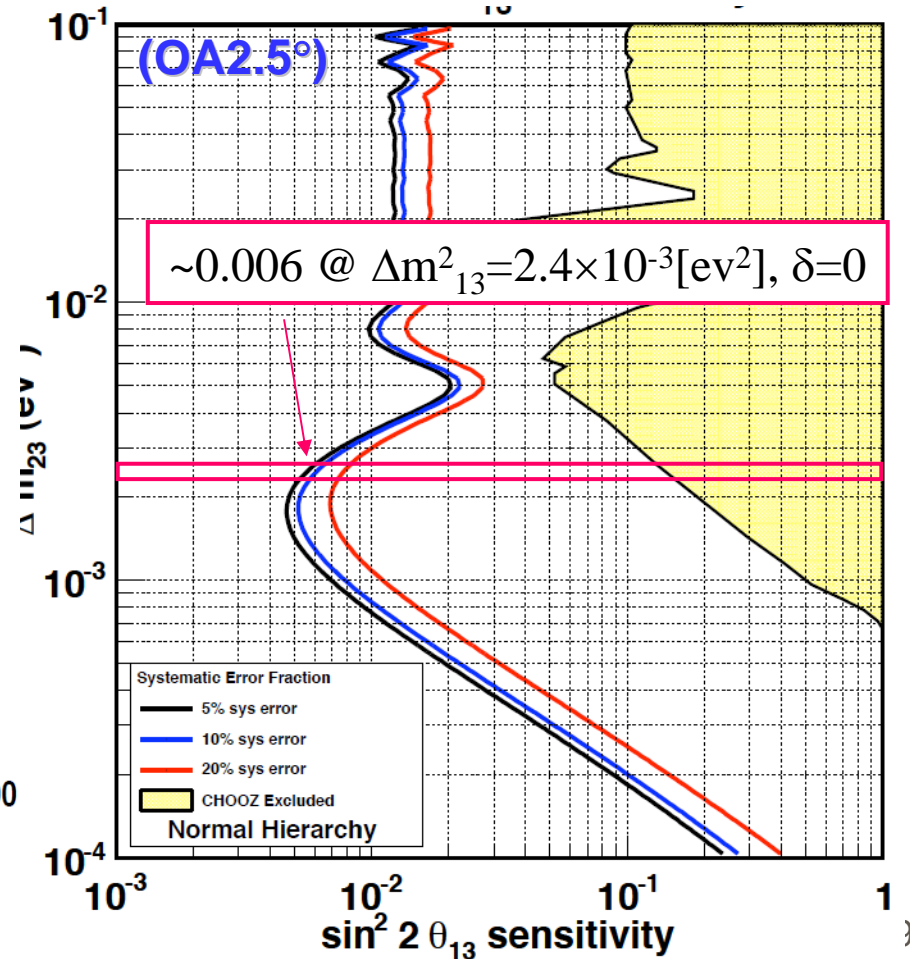
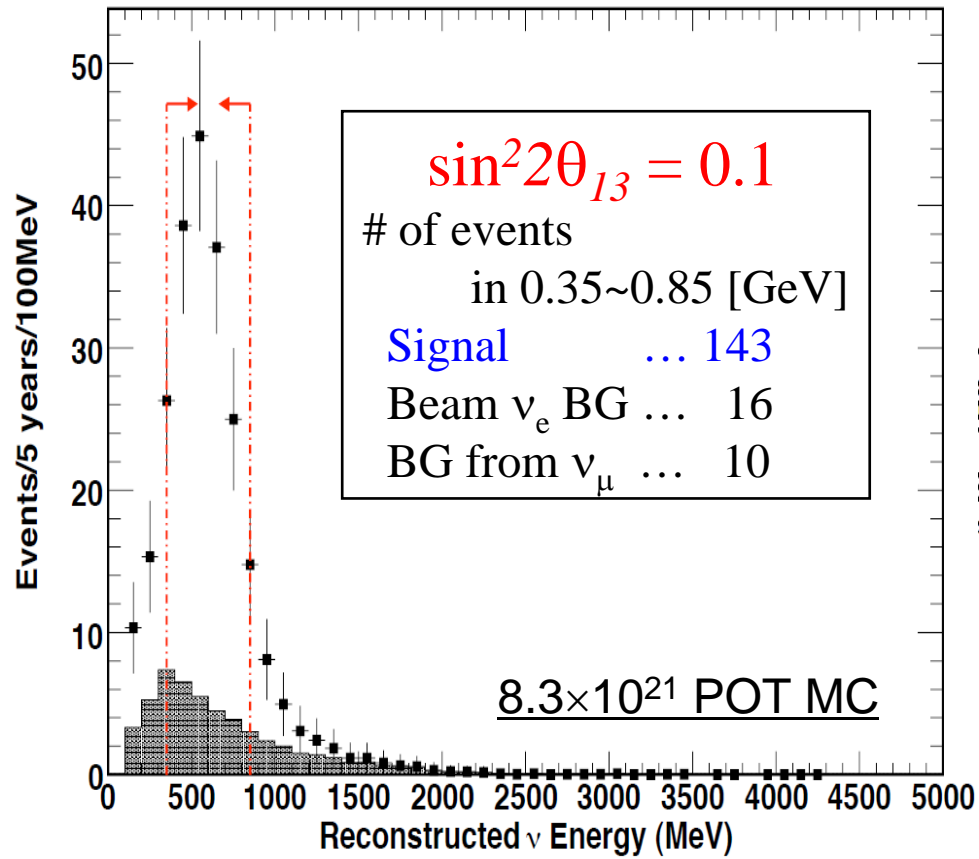
Prospects in T2K

● ν_e appearance

T2K 90%CL sensitivity

$\sin^2 2\theta_{23} = 1.0$ is assumed.

8.3×10^{21} POT



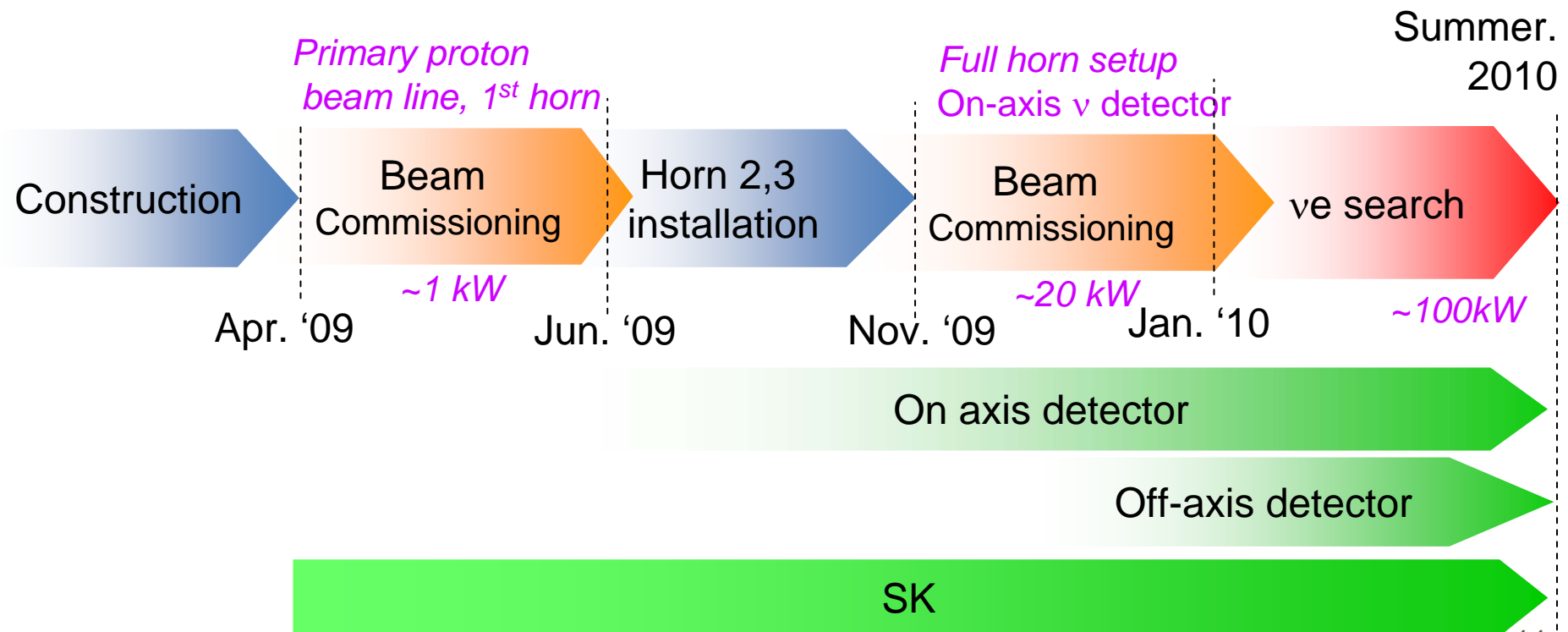
Experimental setup & status



- Experimental setup & status
 - Status in 2009~2010
 - Accelerators
 - Neutrino Beam line
 - Hadron production measurement: *CERN NA61*
 - Near & Far detector

T2K status in 2009~2010

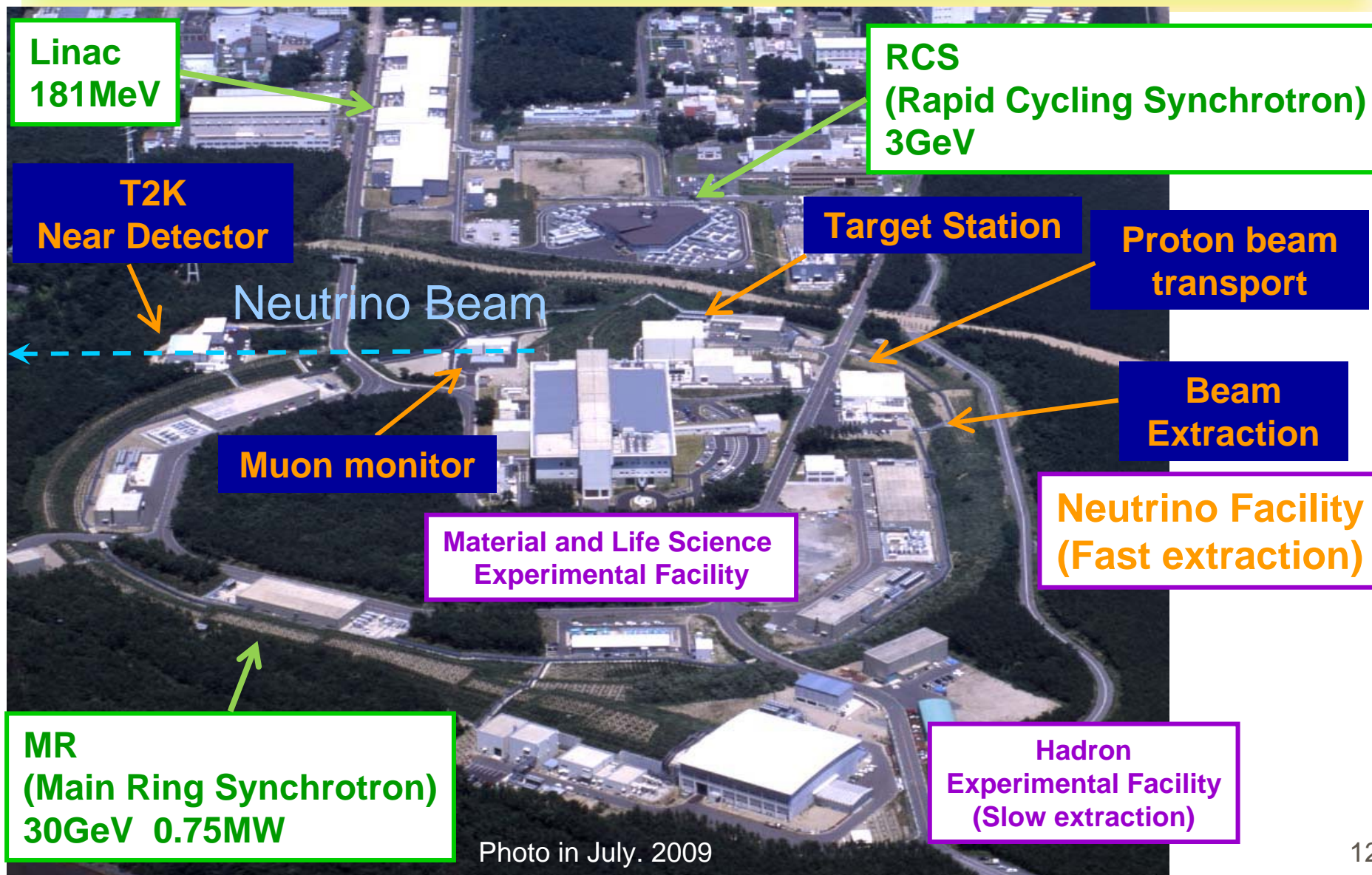
- Beam line construction finished Mar. 2009.
- Current status: ν_e appearance search started!
 - Beam line parameters are fixed.
 - SK is accumulating data stably.
 - Near detector is starting data accumulation.





J-PARC: Accelerators & exp. facilities

Joint project by JAEA and KEK

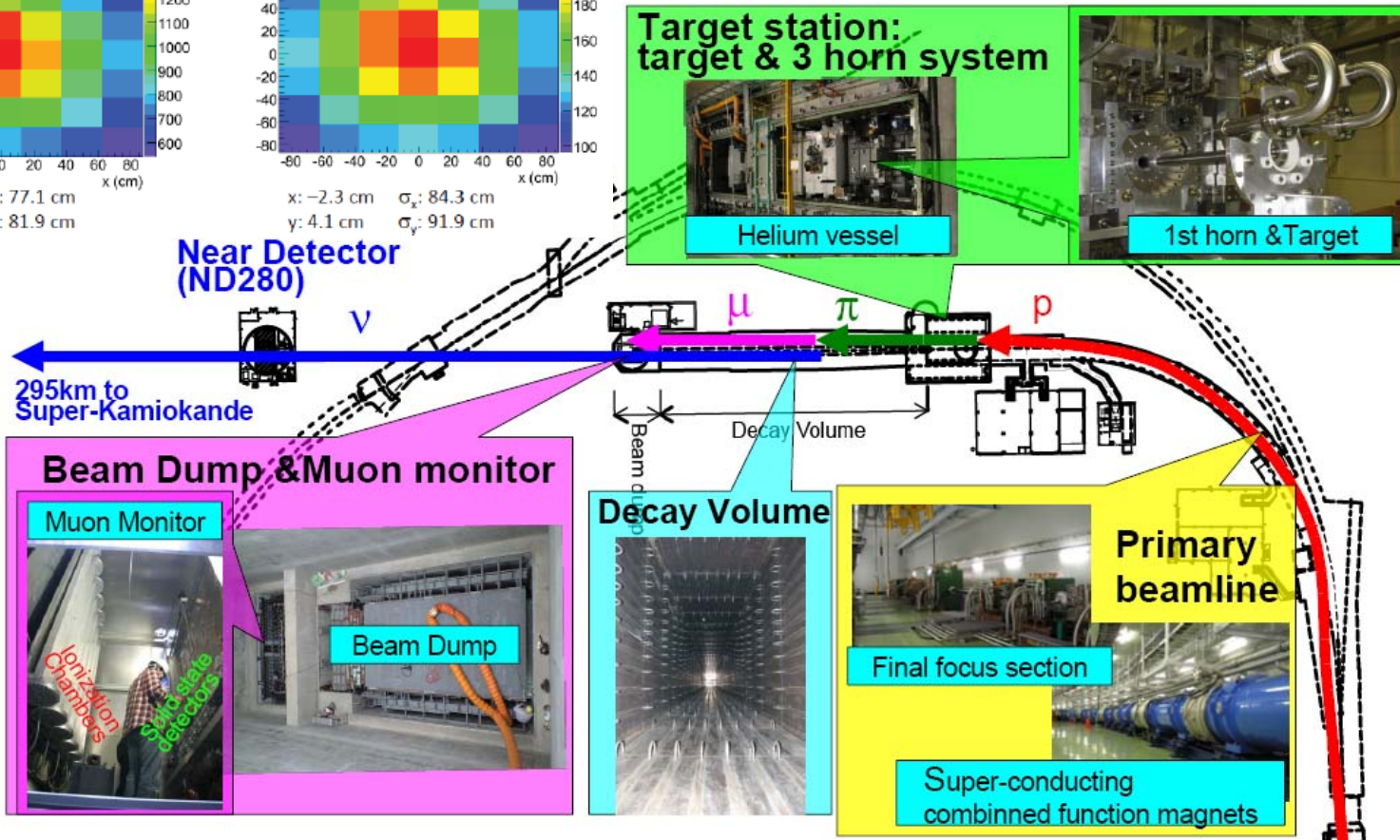
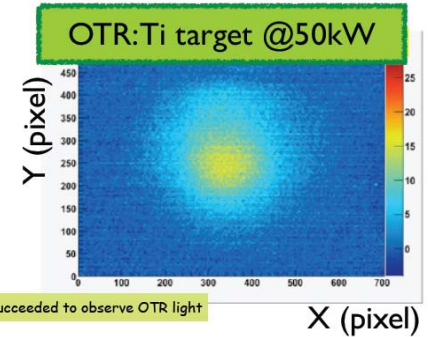
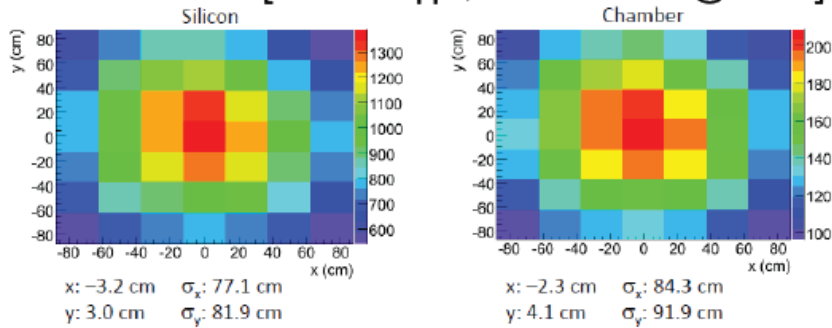


Beam line commissioning

Beam direction is tuned using muon profile.

Beam orbit at the target is tuned using OTR monitor.

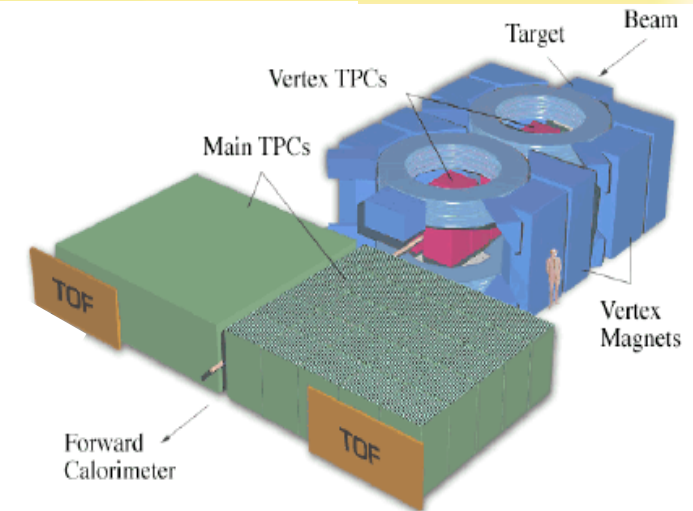
Muon monitor [4.5×10^{12} ppb, 1 bunch 3Horns@320kA]



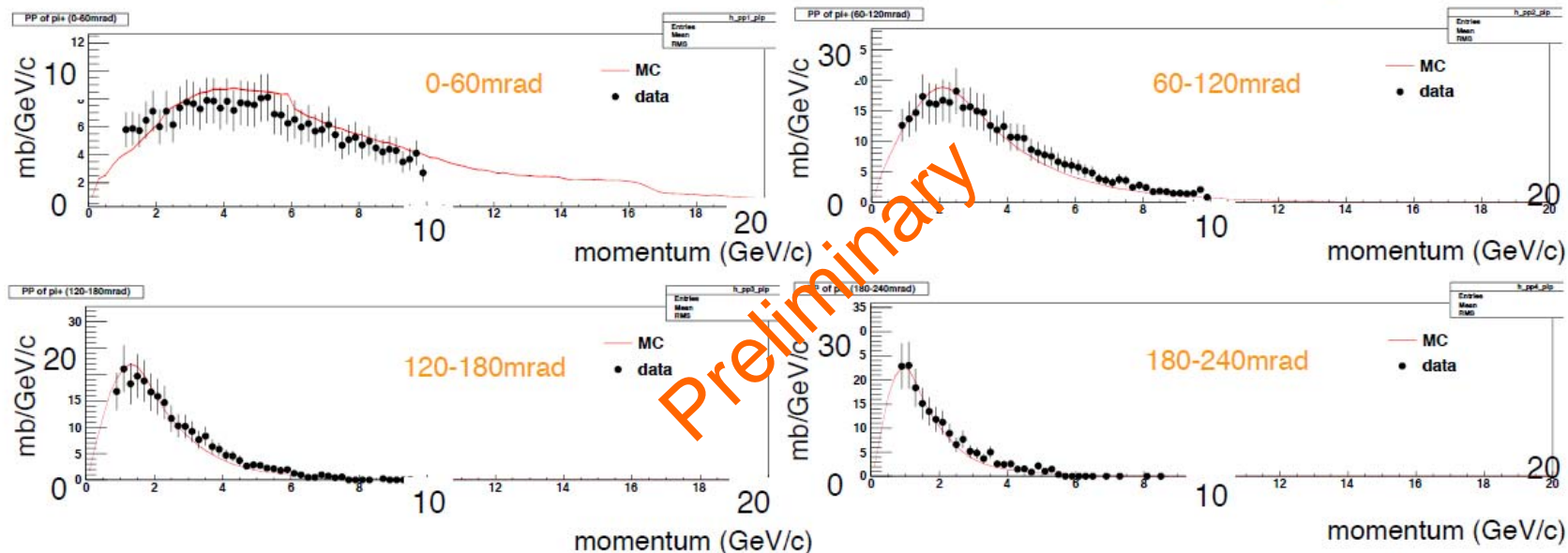
Hadron production measurement

● CERN NA61

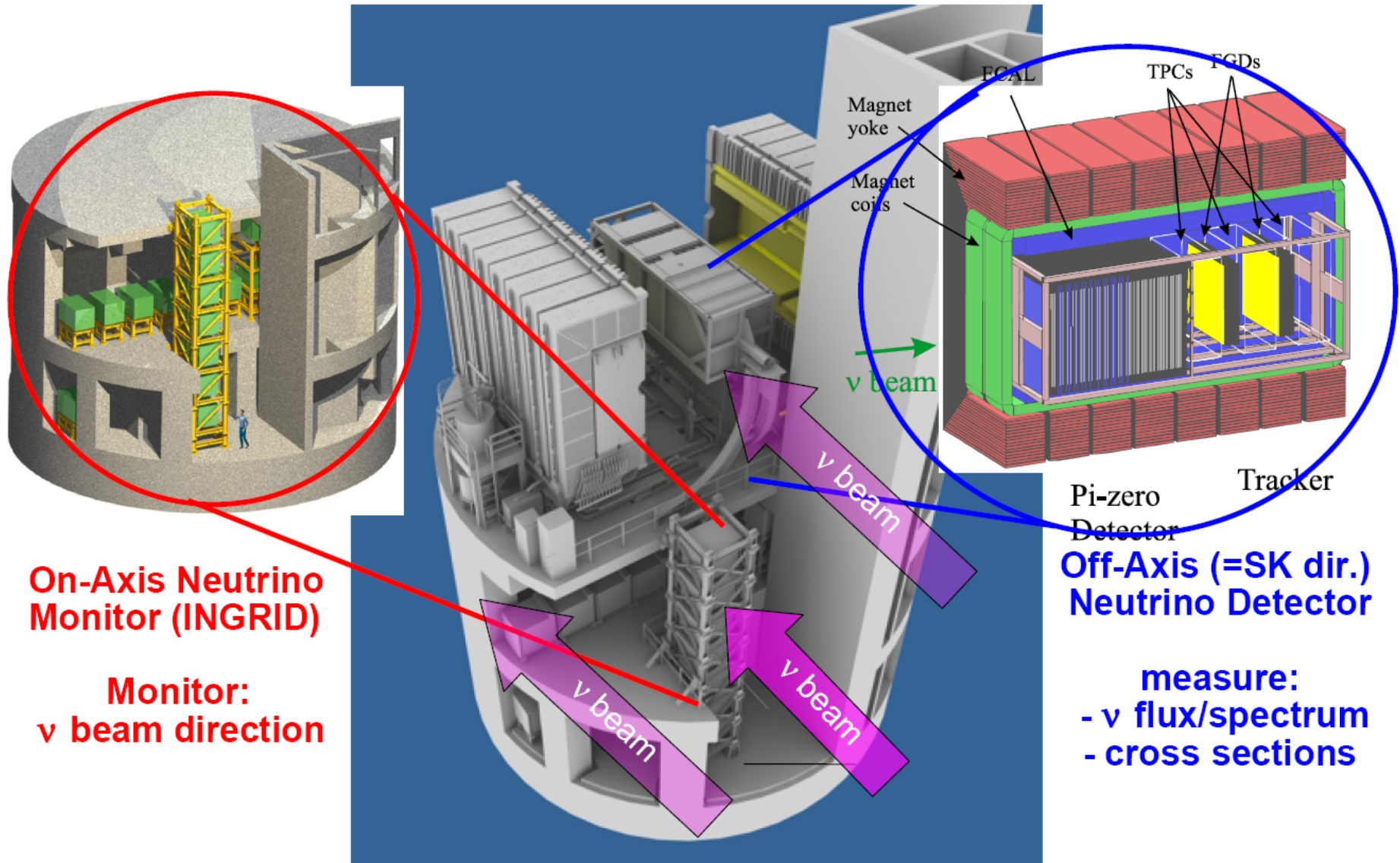
- Data was taken in 2007 and 2009.
 - p (30GeV) + C (thin target or thick target)
- Preliminary result of π production for thin target data was released.
 - It will be implemented in T2K beam MC.



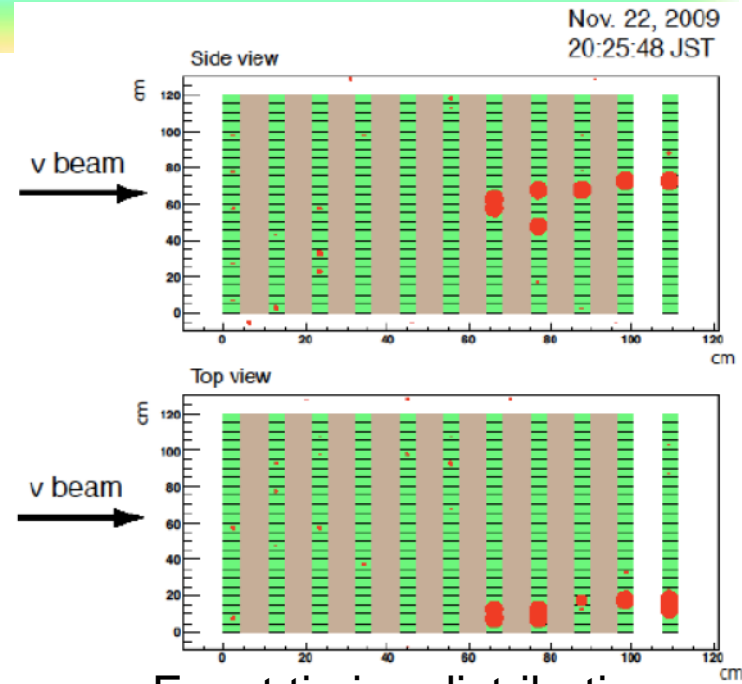
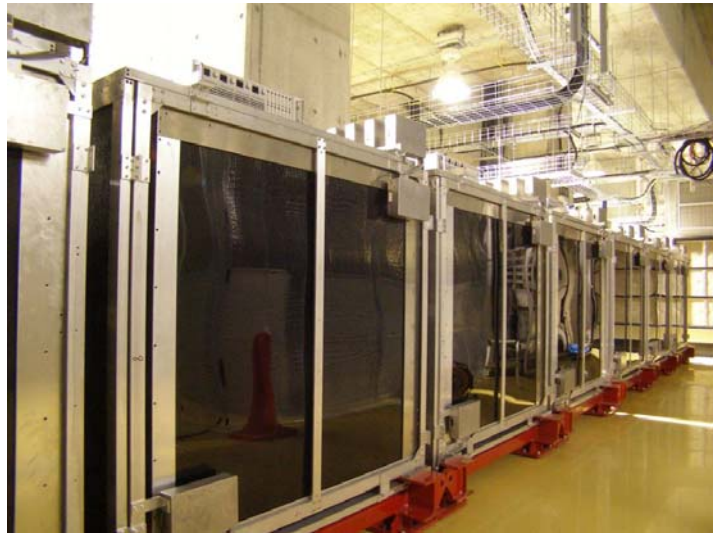
NA61 π production cross section with comparison to the model used in T2K beam MC.



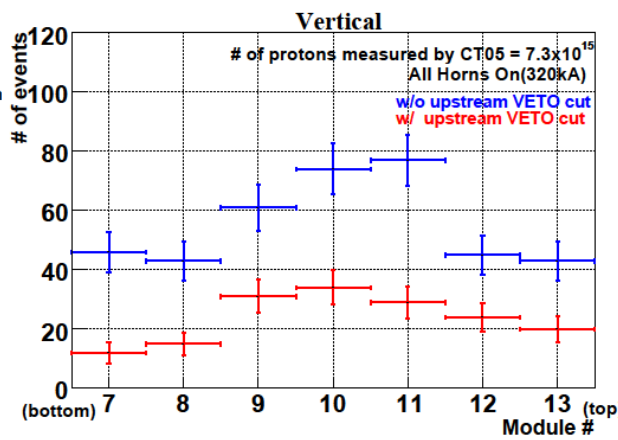
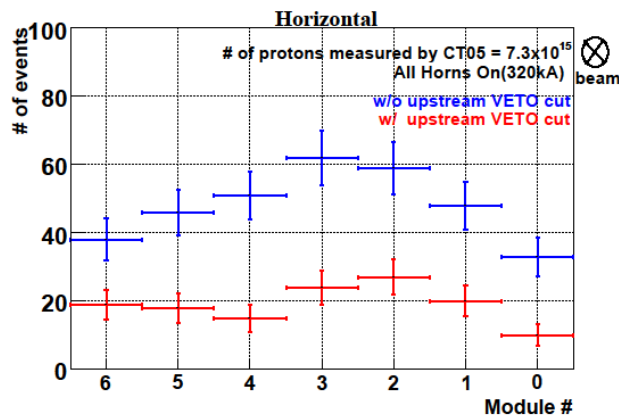
2 Near Detectors



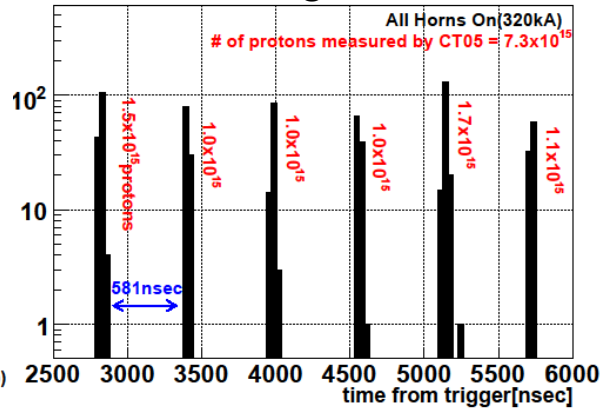
On-axis detector



Beam timing event distribution

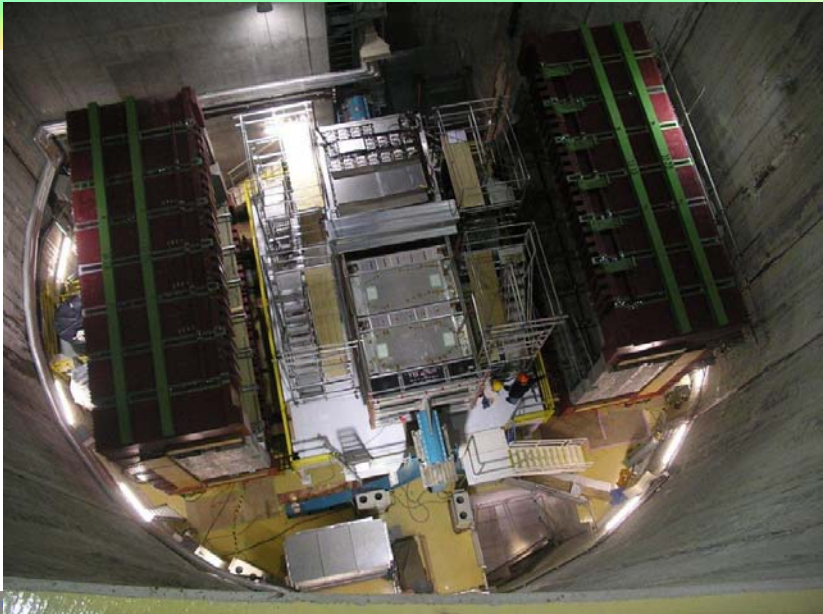
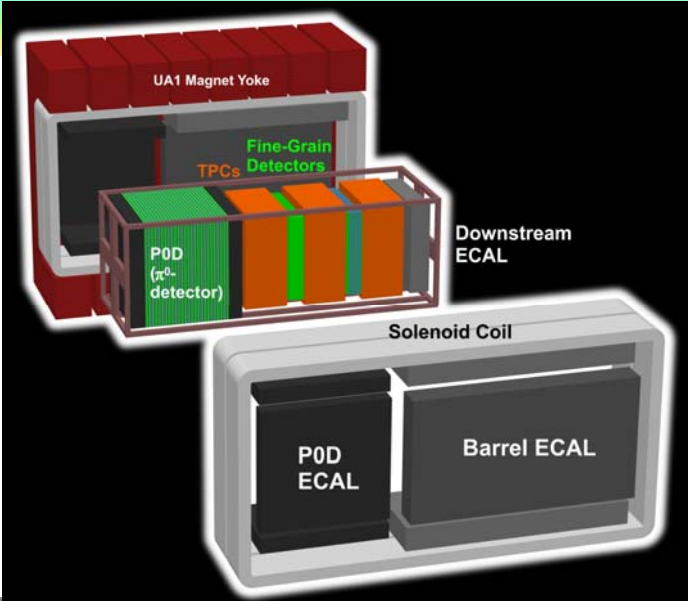


Event timing distribution



Beam direction measurement is started.

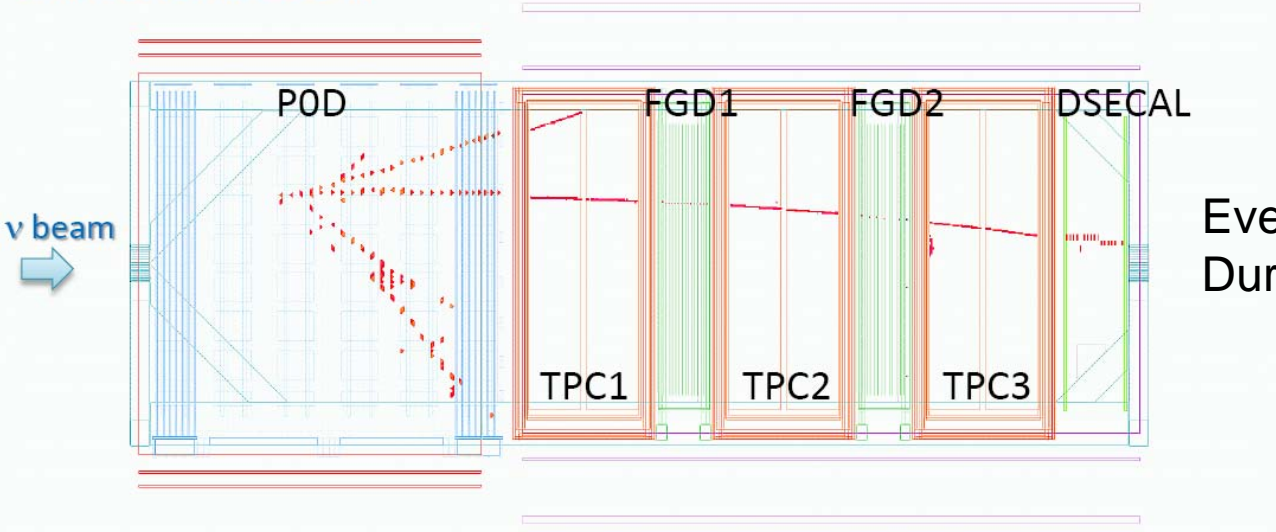
OFF axis detector



Event number : 1609 | Partition : 03 | Run number : 2583 | Split : 7205 | Subrun number : INVALID | Time : Fri 2010-02-05

Magnet on (0.188 T)

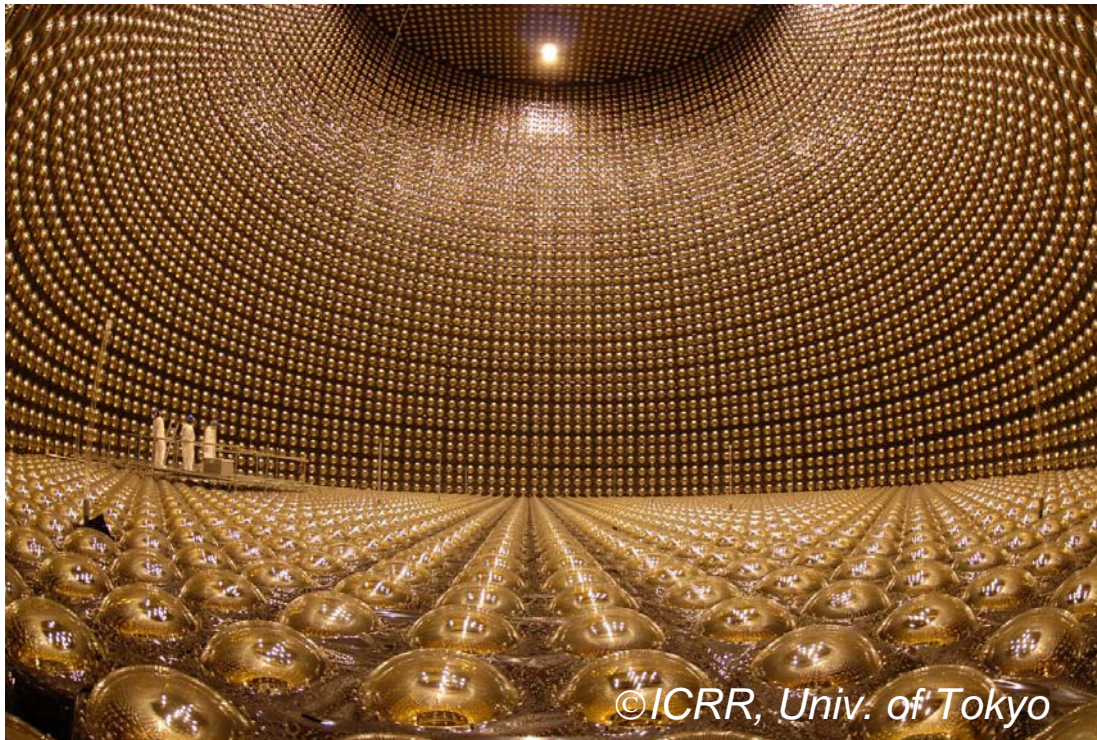
01:57 JST, Feb. 5, 2010



Event display for beam event
During Magnet test operation.

Far Detector: SK-IV

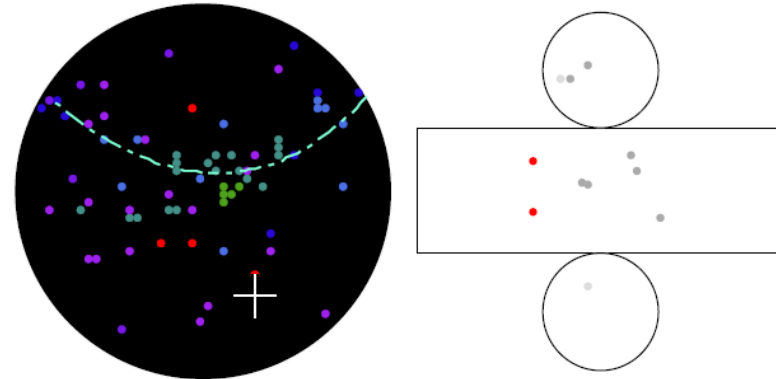
- 50kt Water Cherenkov detector.
- 20' PMT×10,000 + Anti counter PMT×2000 : 40% Photo coverage
- New readout electronics is installed in 2008 summer.
 - Stable & dead time less DAQ system
- Beam related events are selected by event timing using GPS system.
 - Beam timing is sent via network and used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



First ν event candidate @ SK

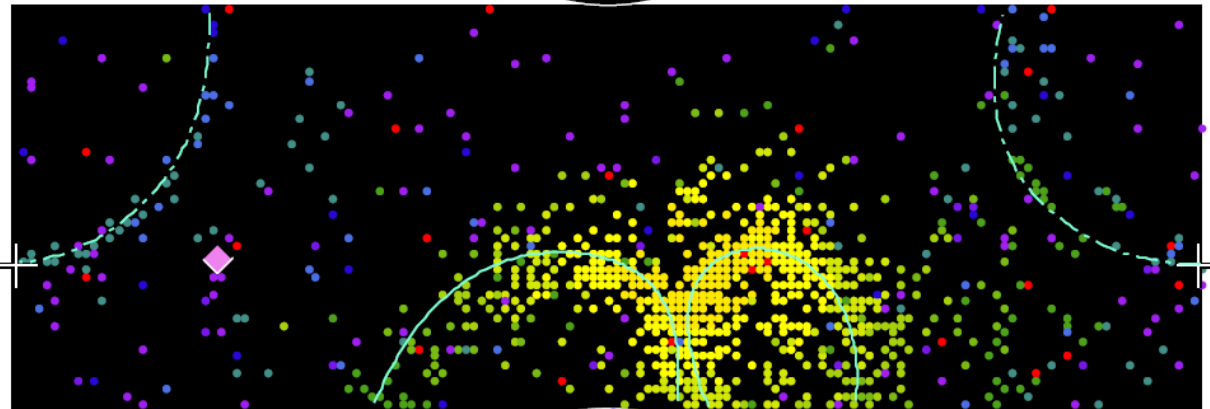
Super-Kamiokande IV

T2K Beam Run 0 Spill 1143942
Run 66498 Sub 160 Event 37004533
10-02-24:06:00:10
T2K beam dt = 2362.3 ns
Inner: 1265 hits, 2344 pe
Outer: 2 hits, 1 pe
Trigger: 0x80000007
D_{wall}: 650.3 cm



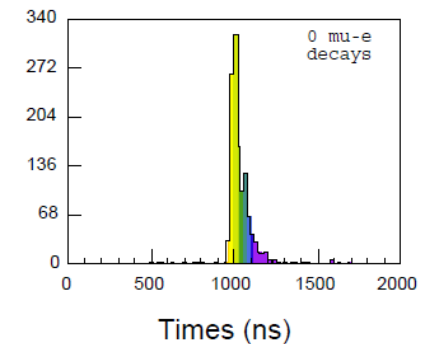
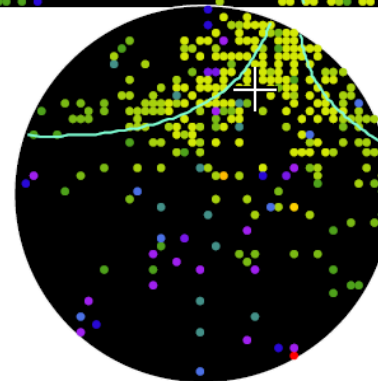
Time (ns)

• < 918
• 918- 933
• 933- 948
• 948- 963
• 963- 978
• 978- 993
• 993-1008
• 1008-1023
• 1023-1038
• 1038-1053
• 1053-1068
• 1068-1083
• 1083-1098
• 1098-1113
• 1113-1128
• >1128



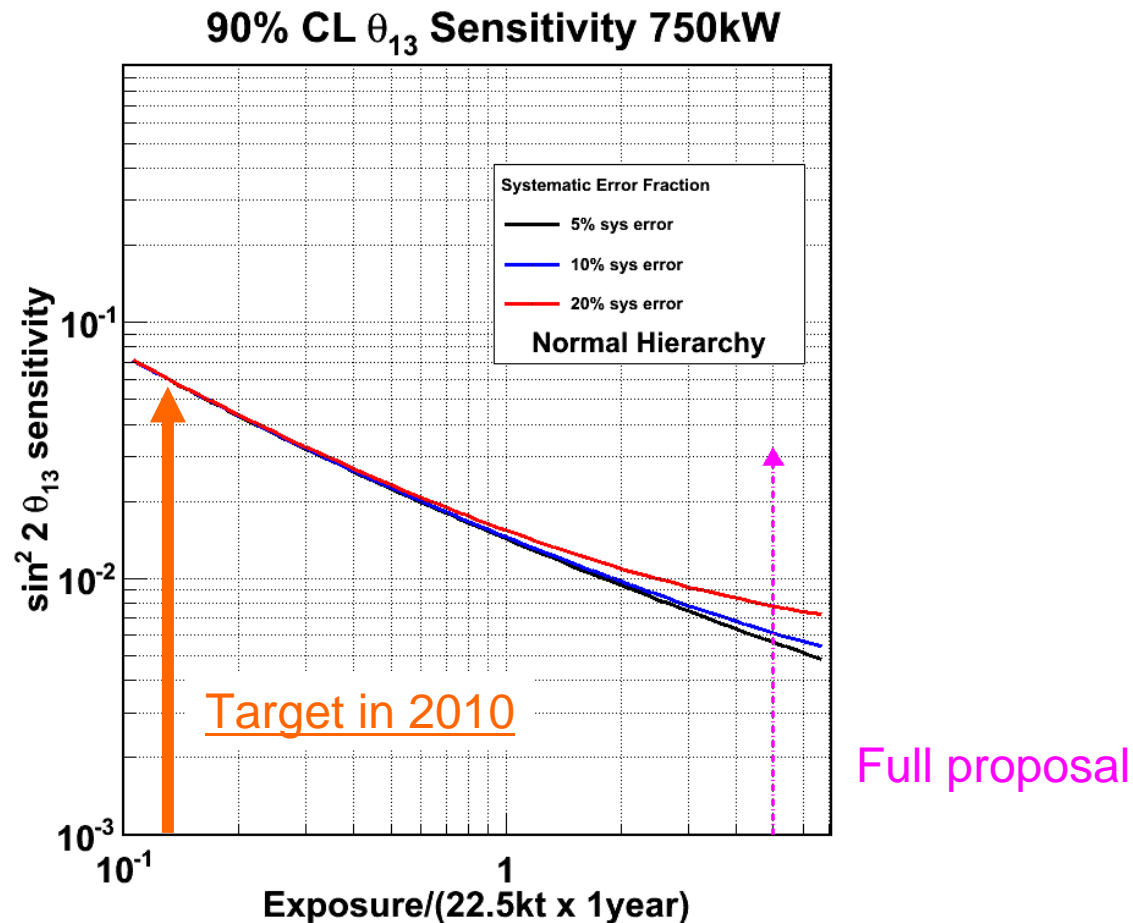
2010/2/24 6:00:06

- Fully contained (No OD activity)
- Inside the Fiducial Volume
- On timing



Prospects in 2010

- Full proposal: 750kW, 5×10^7 sec.
- Short term goal in 2010: Accumulate 100kW x 10^7 sec data.
← It is endorsed by J-PARC PAC.



Summary

- T2K : Long-baseline ν experiment.
 - Search $\nu_{\mu} \rightarrow \nu_e$ oscillation.
 - Determine remaining ν mixing angle: θ_{13} .
- Commissioning is completed in 2009.
 - νe search has started.
 - First neutrino event at SK detected.
- Next milestone: Accumulate $100\text{kW} \times 10^7$ sec in 2010.
 - Reach the current θ_{13} limit and demonstrate the prospects of T2K experiment.
- Ultimate goal : 90% CL sensitivity
 - $\sin^2 2\theta_{13} : 0.006$ ($\Delta m_{23}^2 = 2.4 \times 10^{-3} \text{eV}^2$, 10% BG syst. error)

backup



Expected beam power

M.Yoshioka (KEK) J-PARC PAC 2010/1/15

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

