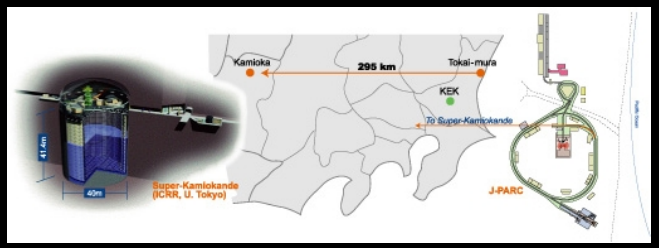
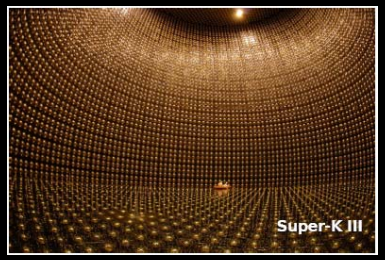
Approved long baseline experiments (non-CNGS)

MINOS

NOVA





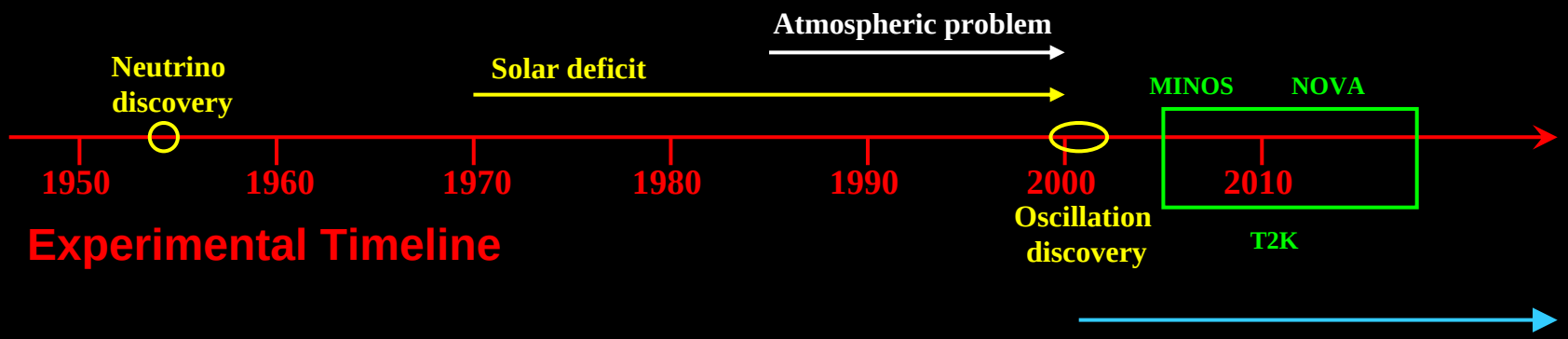
T2K

Christos Touramanis

UNIVERSITY OF LIVERPOOL

NEU2012 meeting
CERN 18 March 2009

MINOS – NOVA - T2K
current non-European long baseline projects



Note:
Significant European contribution to MINOS
Substantial European contribution to T2K

- Discovery
- Precision
- CP search ?
- PMNS ?

Neutrino mixing

Flavor eigenstates

$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = \begin{bmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{\mu 1} & U_{\mu 2} & U_{\mu 3} \\ U_{\tau 1} & U_{\tau 3} & U_{\tau 3} \end{bmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

Mass eigenstates

$$U = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix} \cdot \begin{pmatrix} c_{13} & 0 & s_{13}e^{-i\delta_{\mathrm{CP}}} \\ 0 & 1 & 0 \\ -s_{13}e^{i\delta_{\mathrm{CP}}} & 0 & c_{13} \end{pmatrix} \cdot \begin{pmatrix} c_{21} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} e^{i\eta_1} & 0 & 0 \\ 0 & e^{i\eta_2} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

Atmospheric (+ ν_μ Long BL)

ν_μ Long BL reactor Short BL

Solar (+ reactor Long BL)

Majorana ??

$c_{ij} = \cos(\theta_{ij})$

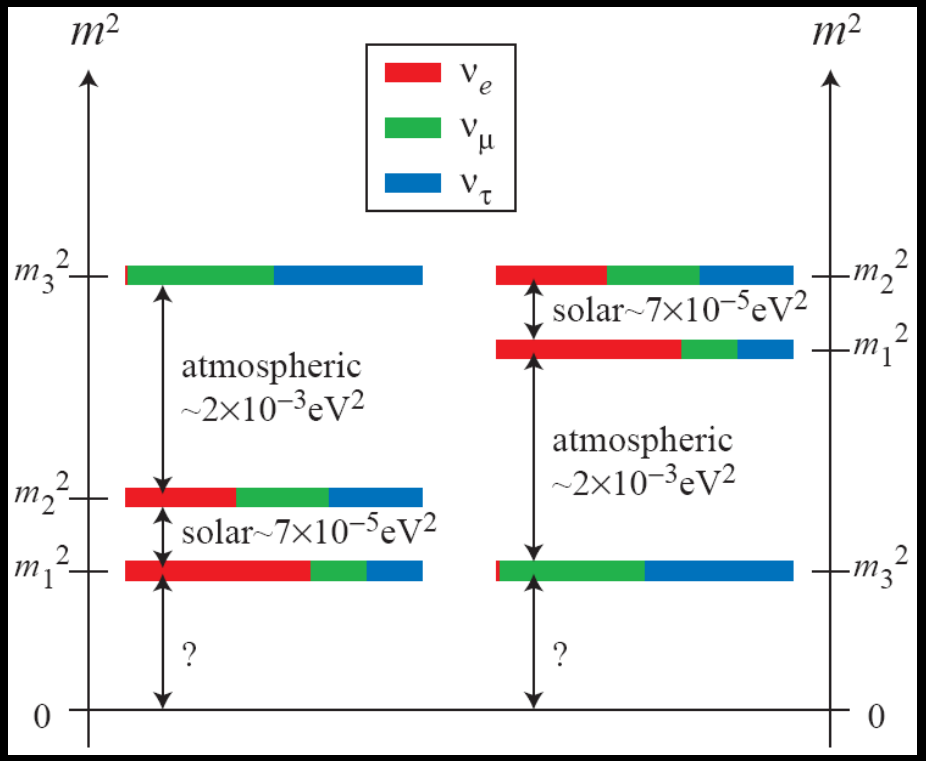
$s_{ij} = \sin(\theta_{ij})$

2-neutrino oscillation

$$P_{\alpha\beta} = \delta_{\alpha\beta} - (2\delta_{\alpha\beta} - 1)\sin^2(2\theta)\sin^2\left(1.27 \bullet \Delta m^2 \bullet \frac{L}{E}\right)$$

Neutrino oscillations and Long Baseline Experiments

Mass hierarchy

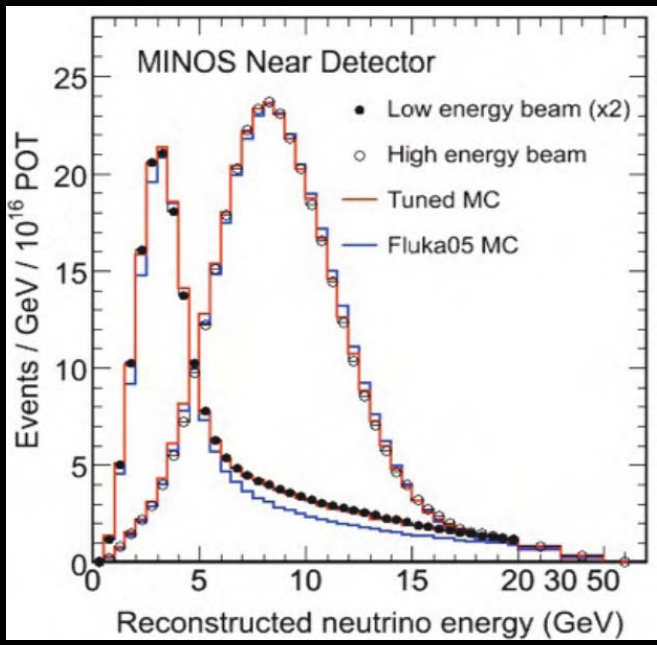


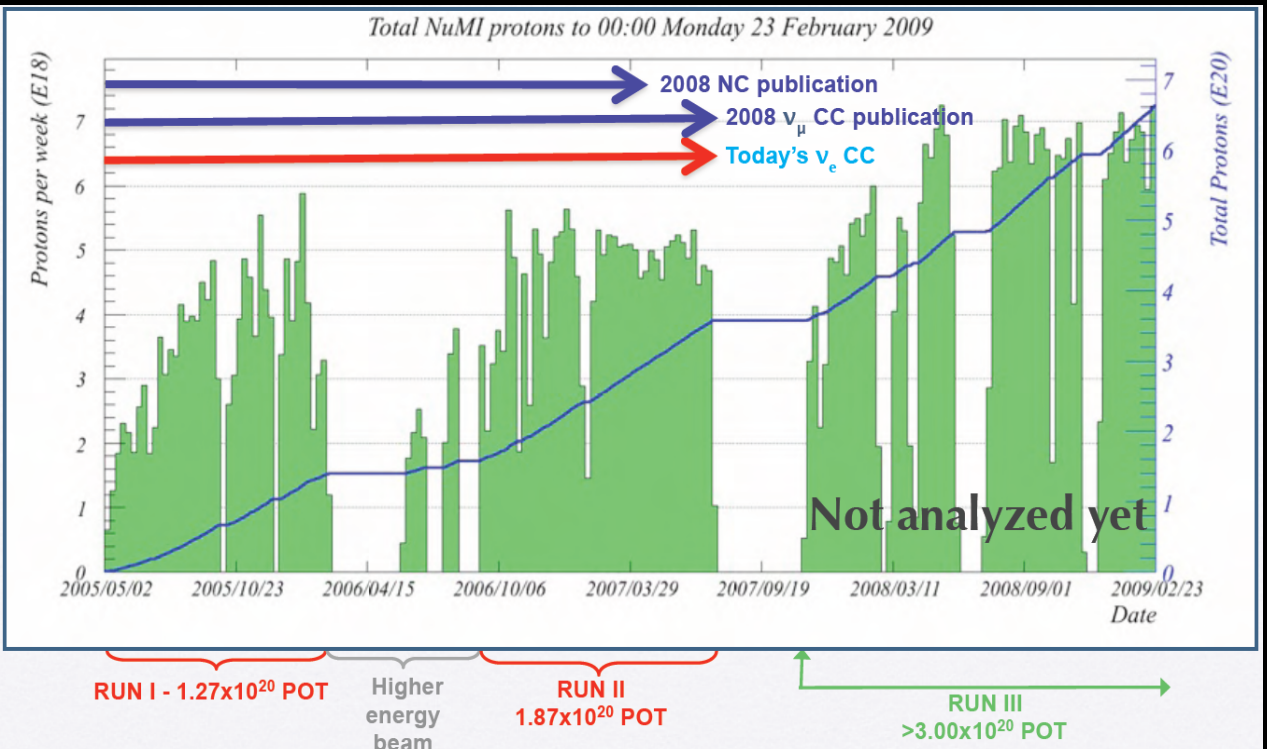
normal **inverted**

- Is θ_{13} non-zero?
- CP violation?
- Is θ_{23} 45^0?
- Which hierarchy?

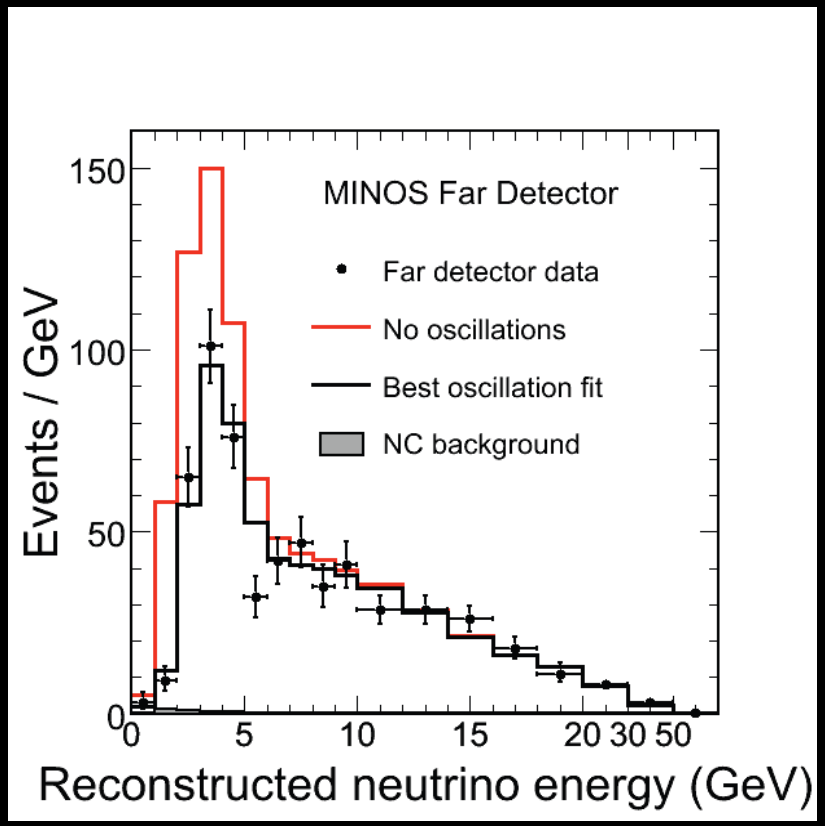
MINOS

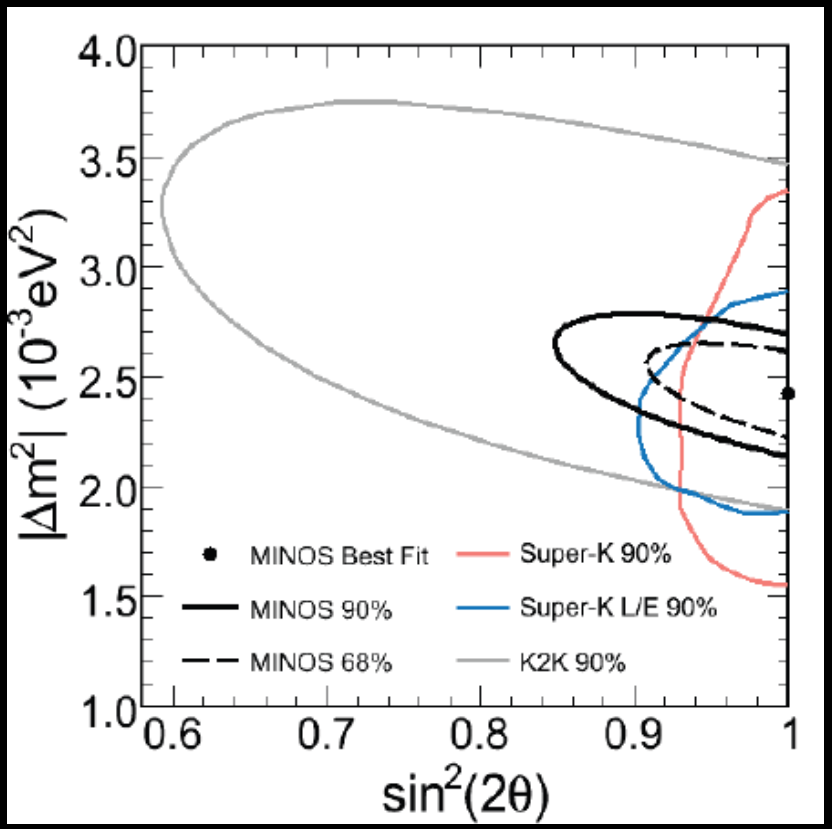
- 150 members, mainly American
- Some Europeans (UK, France, Poland, Greece)
- Data-taking since 2005
- 735km, NuMI@FNAL: low and high E runs
- Antineutrino running possible
- Magnetized iron / scintillator tracking calorimeter detectors
- 5.4kton Far detector
- 0.98kton Near detector





MINOS – disappearance results





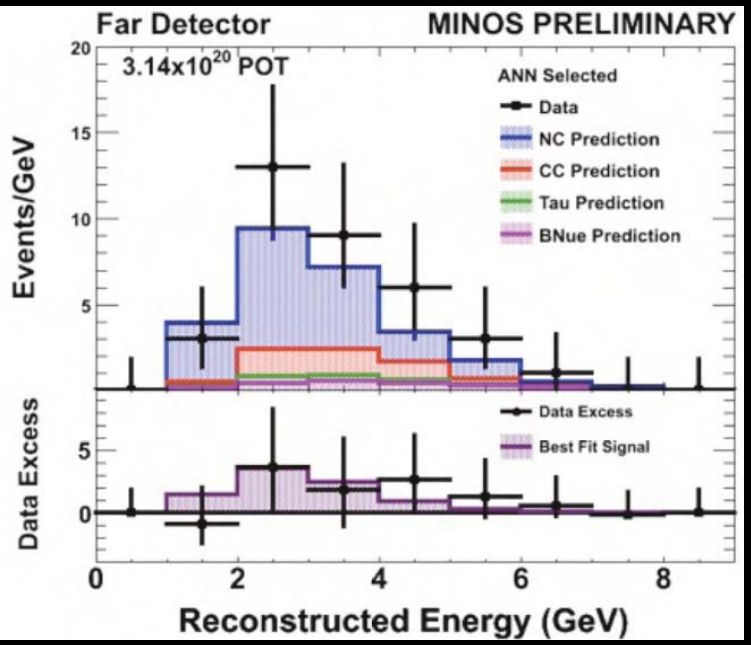
$|\Delta m^2_{32}| = 2.43 \pm 0.13 \times 10^{-3}$ eV^2 (68% C.L.)

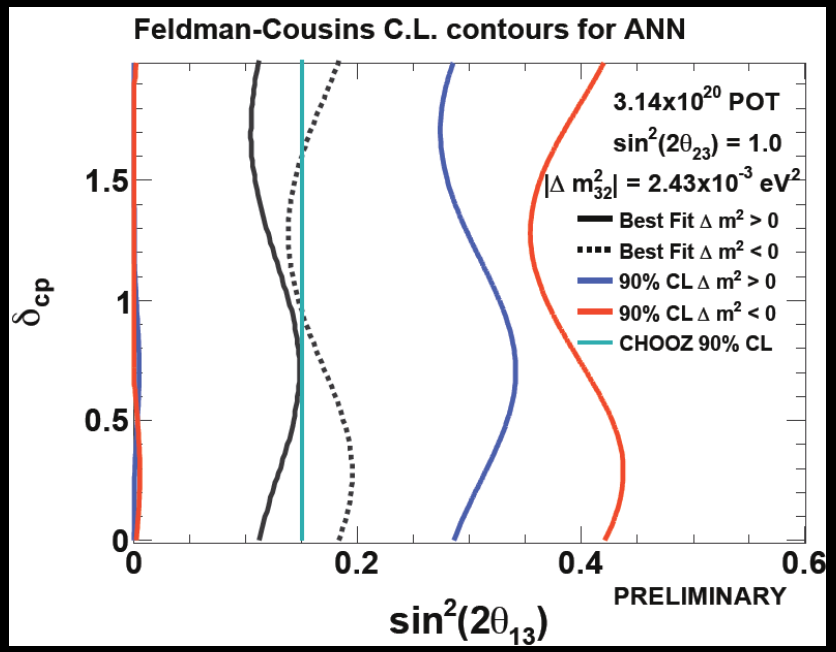
$\sin^2(2\theta_{23}) > 0.90$ (90% C.L.)

With χ^2/NDF=90/97

MINOS – appearance results, MORIOND EW 09

Observation 35 events
Expected Background 27±5(stat)±2(sys)
for 3.14 x 10^{20} POT





- normal hierarchy, $\delta_{CP} = 0$: $\sin^2(2\theta_{13}) < 0.29$ (90% CL)
- inverted hierarchy, $\delta_{CP} = 0$: $\sin^2(2\theta_{13}) < 0.42$ (90% CL)

Not conclusive; more statistics (double) to be analyzed
(My) current reading of this: after the first MINOS result we do not have any stronger limit than before
Early evidence and discovery by T2K (and Double-CHOOZ) remains a strong possibility

T2K

- 385 members, 64 Institutes, 12 countries
- 28 institutes from 7 European countries
- Neutrino Beamline construction: 2004-2008; commissioning: 2008-09; first neutrinos: next month
- Beamline cost: $160M
- Near Detector cost: ~$30M
- Beware of financial basis (Japanese ~ CERN ?)

Main T2K Science Objectives

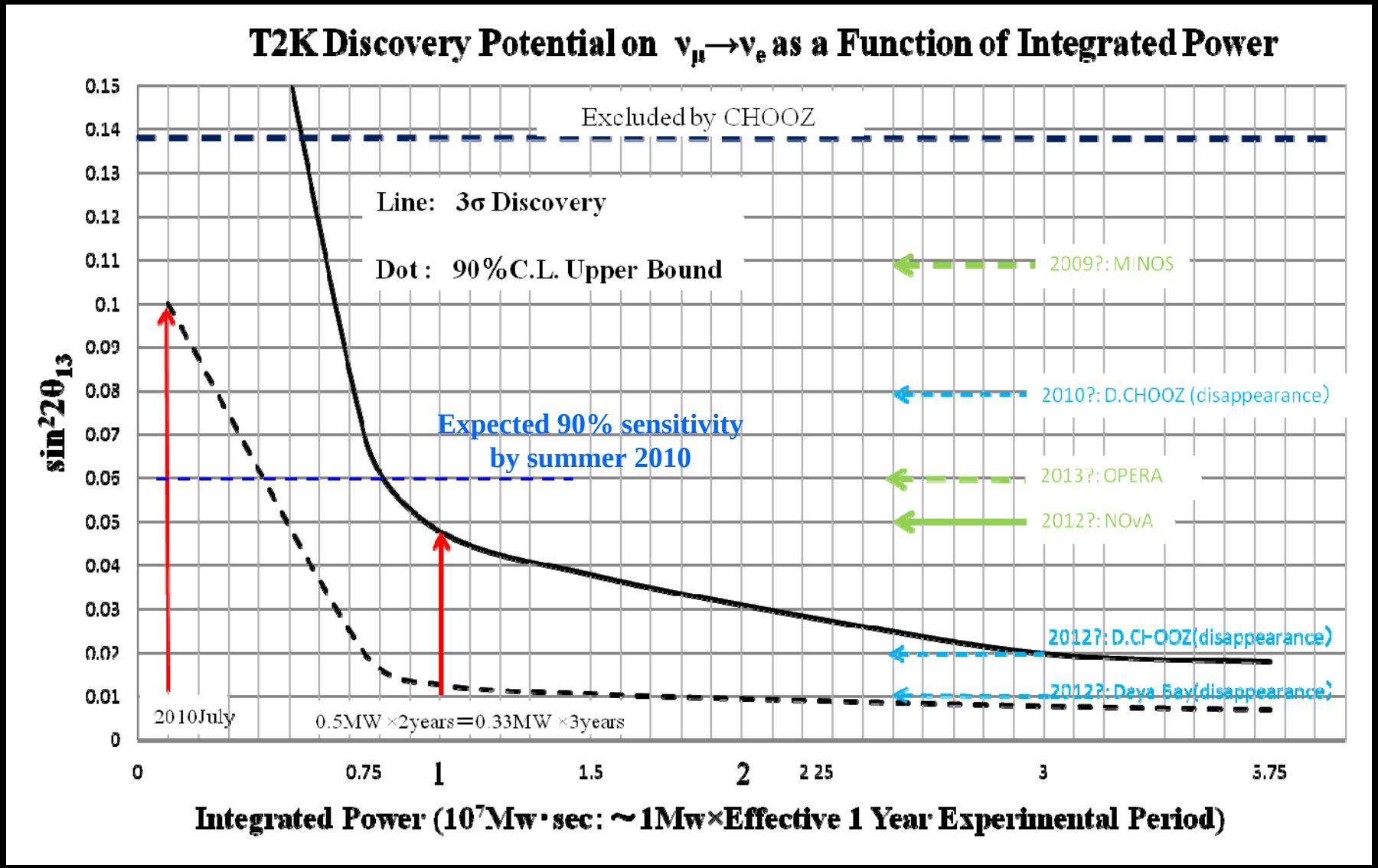
- Discovery: search for non-zero θ_{13}
  - Increase current sensitivity by ~10
  - Outcome crucial for international neutrino programme planning
  - Opens up search for neutrino CP violation
- Precision: θ_{23} , Δm^2_{23}
  - World's most precise measurements

    $\sin^2 2\theta_{23} \rightarrow \approx 1\%$ $\quad$ $\Delta m^2_{23} \rightarrow \approx 2\%$
    - Is 23 oscillation maximal?
    - New symmetry of Nature?
- Neutrino scattering below 1GeV
  - Precision measurements necessary to achieve previous goals
- Clarify mass hierarchy (combined with NOvA ?)

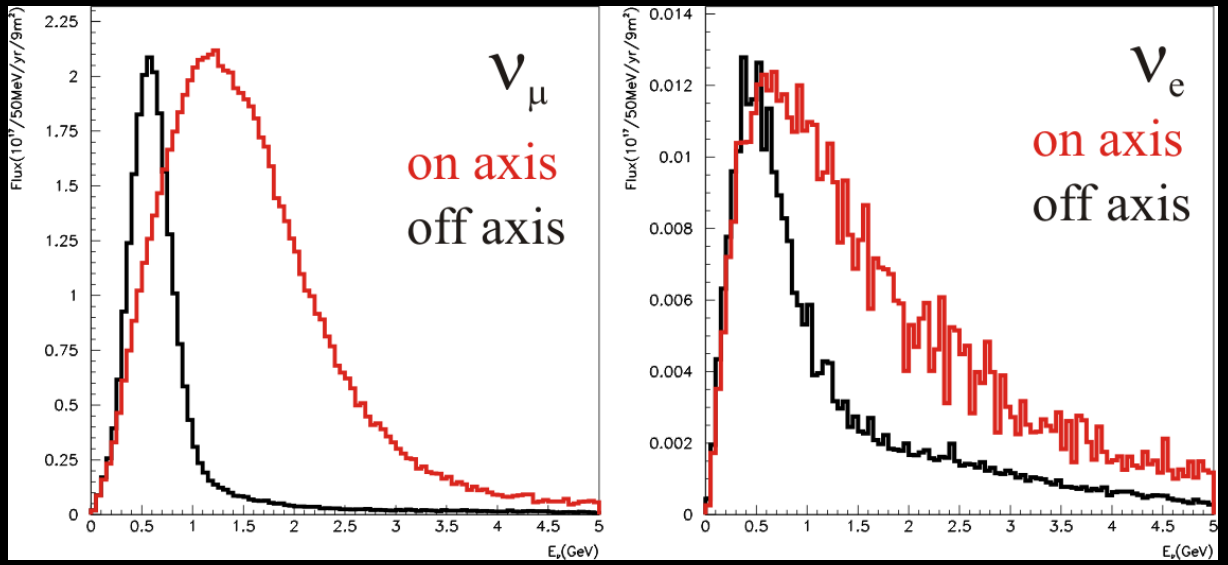
T2K

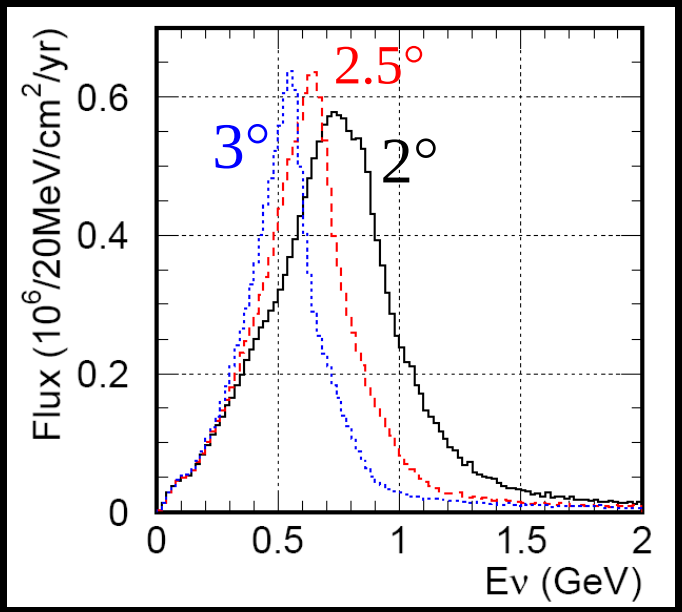
- Super-Kamiokande IV:
- Fully refitted
- New electronics (eliminate dead-time)
- Taking data since 6 months

T2K appearance sensitivity



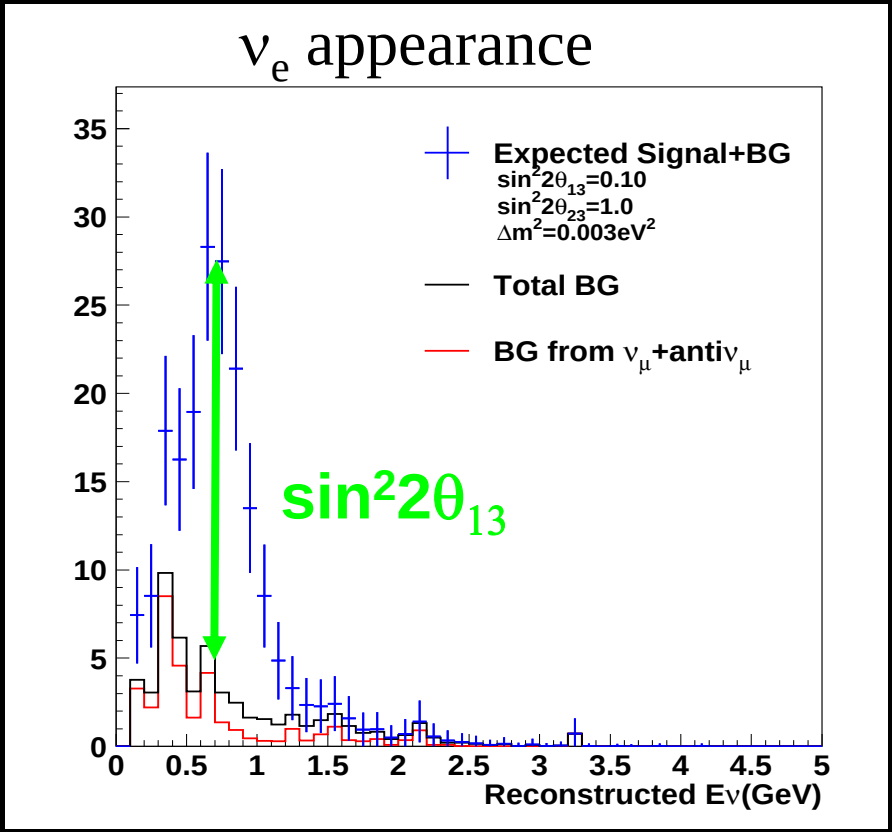
Off-axis neutrino beam

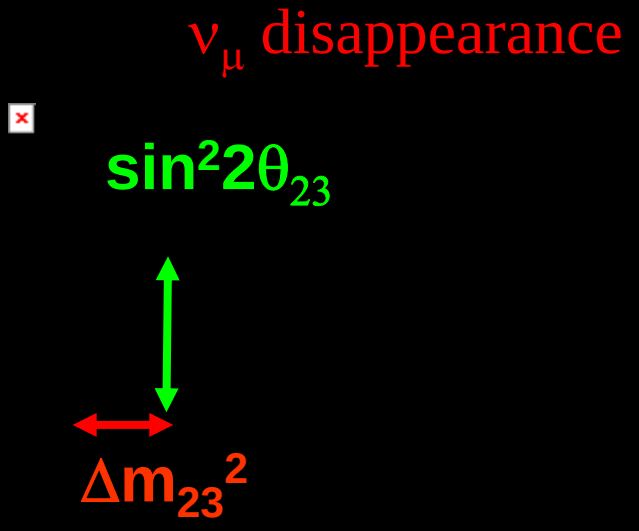




- Quasi-monochromatic ν_μ beam
- L/E tuned for max sensitivity
- Smaller intrinsic ν_e fraction
- Reduced high-E non-CCQE backgrounds

Main T2K measurements





The challenges:

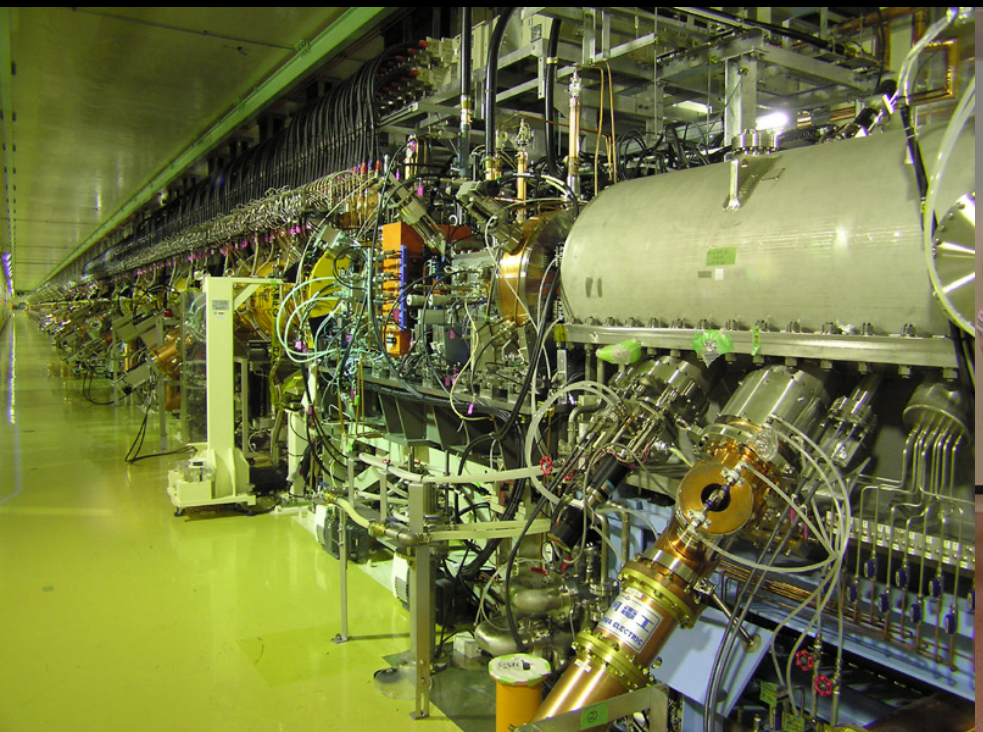
- Knowledge of initial beam content and kinematics
- Knowledge of backgrounds

J-PARC construction since 2001

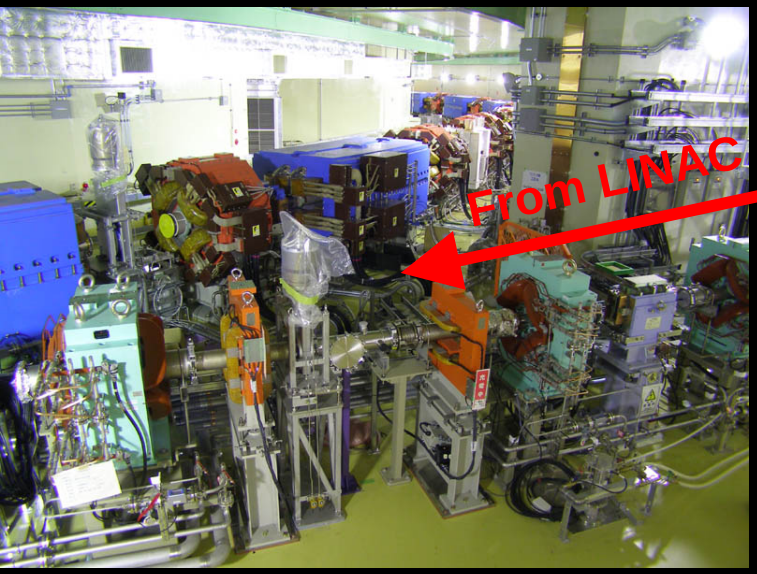
First funds for neutrino project approved in December 2003!

LINAC: commissioned in January 2007

Parameter	Unit	Design	Commissioning goal	Achieved to date
Output energy	MeV	181	181	181
Peak current	mA	30	25	25 30 (RFQ)
Linac beam power	kW	36	1.2	1.2 (w/o chop)
Momentum spread	%	< ± 0.2	< ± 0.2	25 mA: 0.16 (FWHM)
Orbit distorsion	mm	± 1	± 1	± 1
Beam position jitter	mm	± 0.1	± 0.1	± 0.2
Peak current fluctuation	%	± 1	± 1	± 1



3GeV RCS, achieved: 70s @ 213kW, singe-bunch corresponding to 353kW



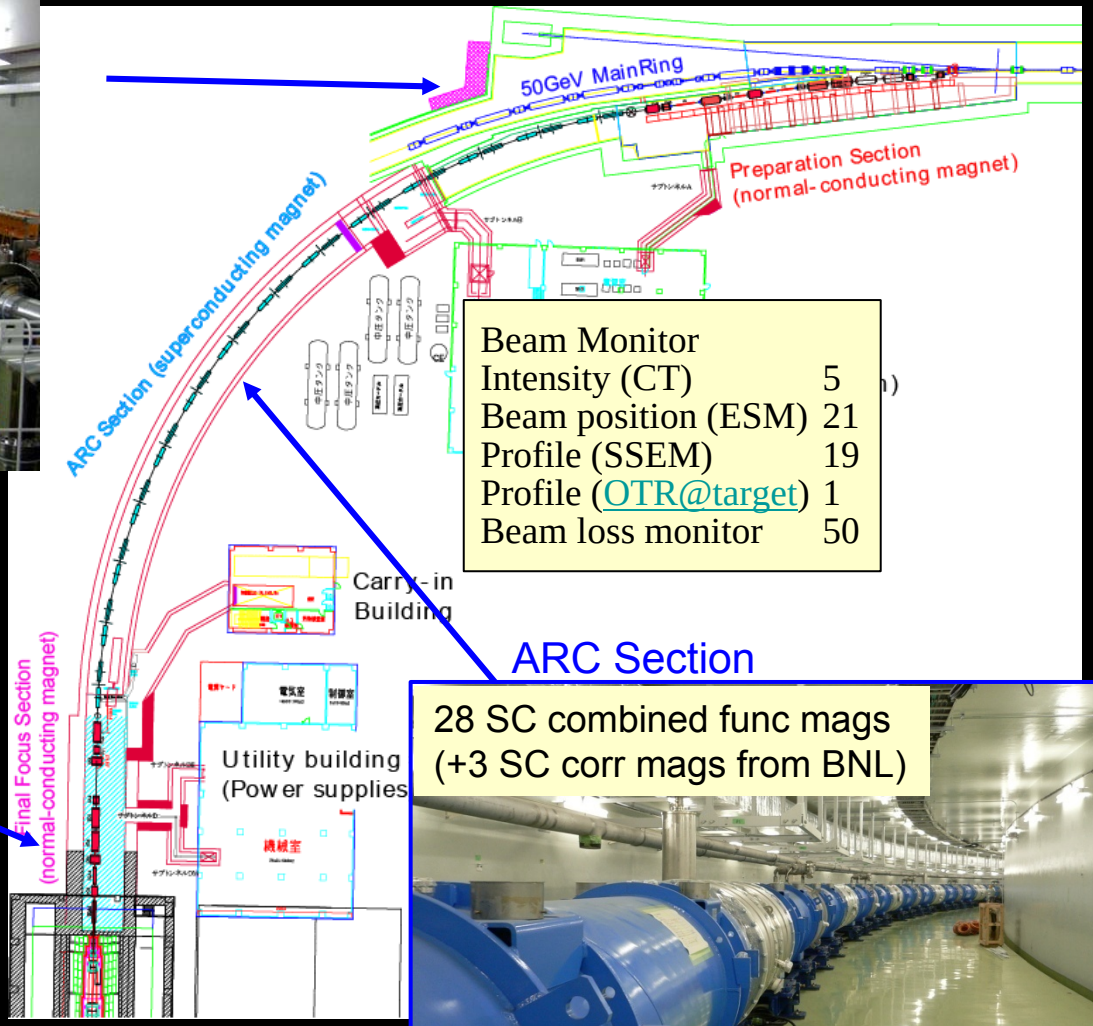
Main Ring

- Phase 1: 30GeV
- Commissioned

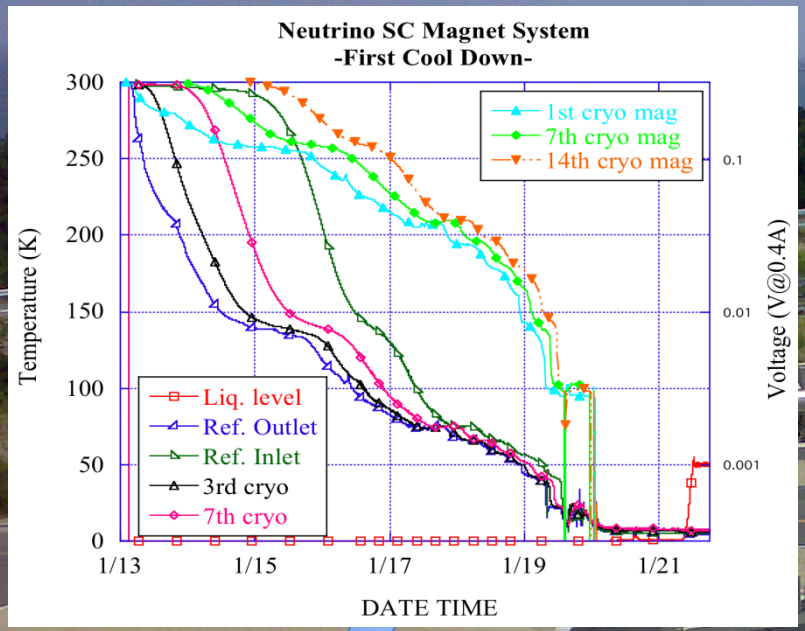
- First neutrinos: April 2009
- Aim to deliver 100kW*10^7s before summer 2010
- Leading to T2K θ_{13} sensitivity below CHOOZ limit

Primary Beam-line

Assumed Beam Loss
750W@Prep.
250W@FF.
(1W/m @ ARC)



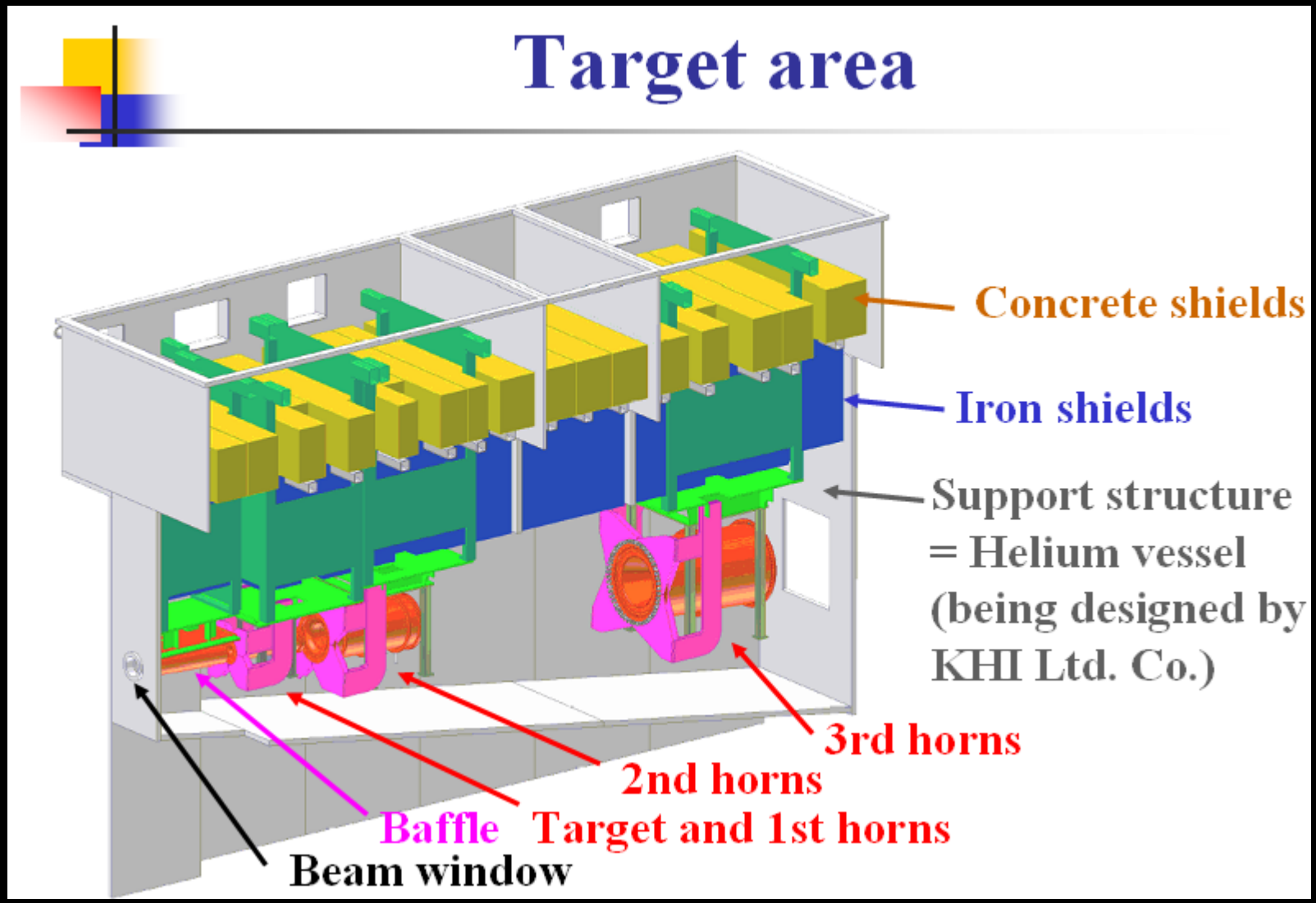
Superconducting Magnet System



- 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

Neutrino target volume

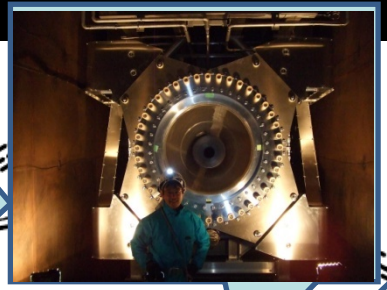


1000m3, 470ton, Helium-filled, passed vacuum test

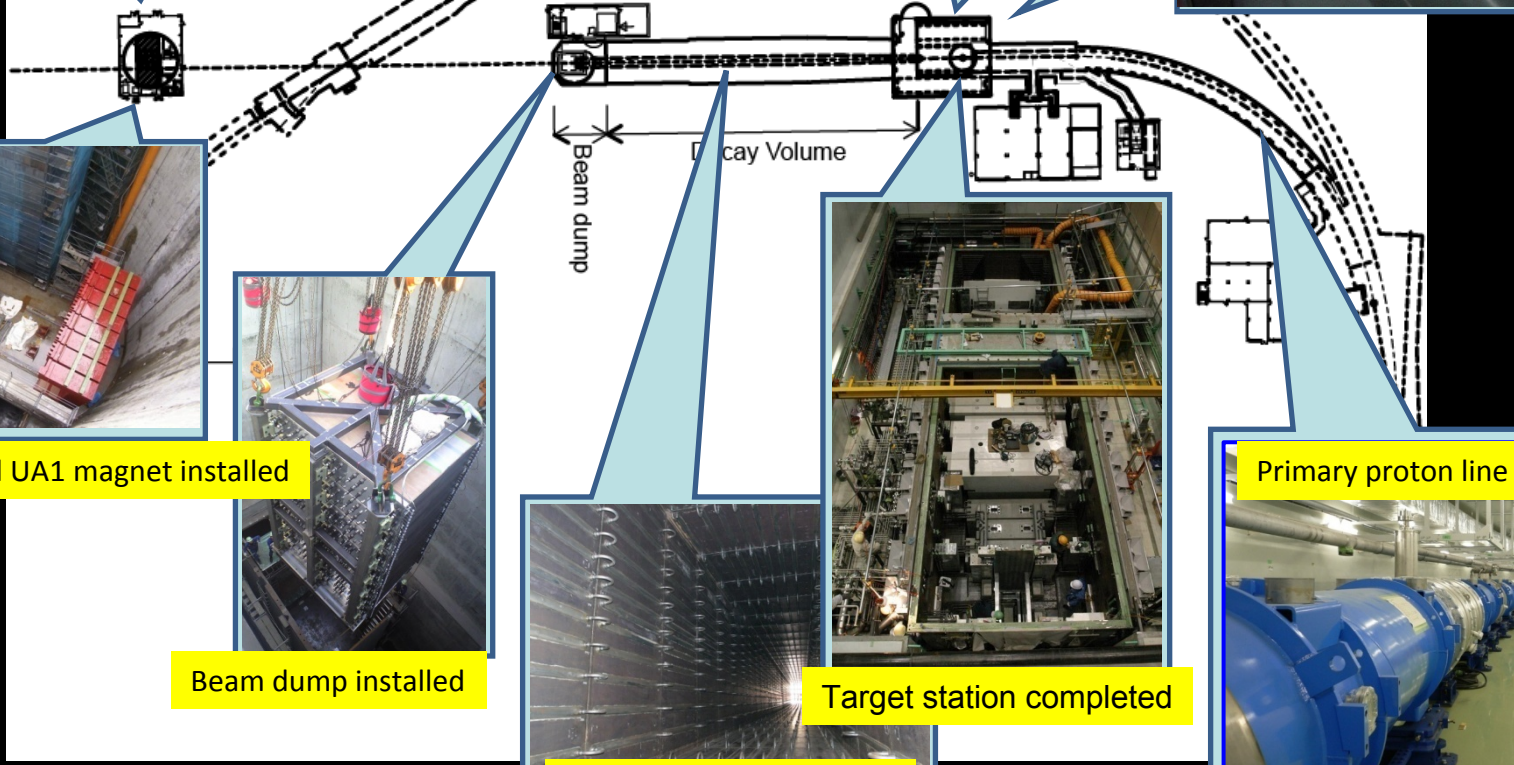
Status of neutrino facility construction

Near Detector Building

Horn



Target



Refubrished UA1 magnet installed

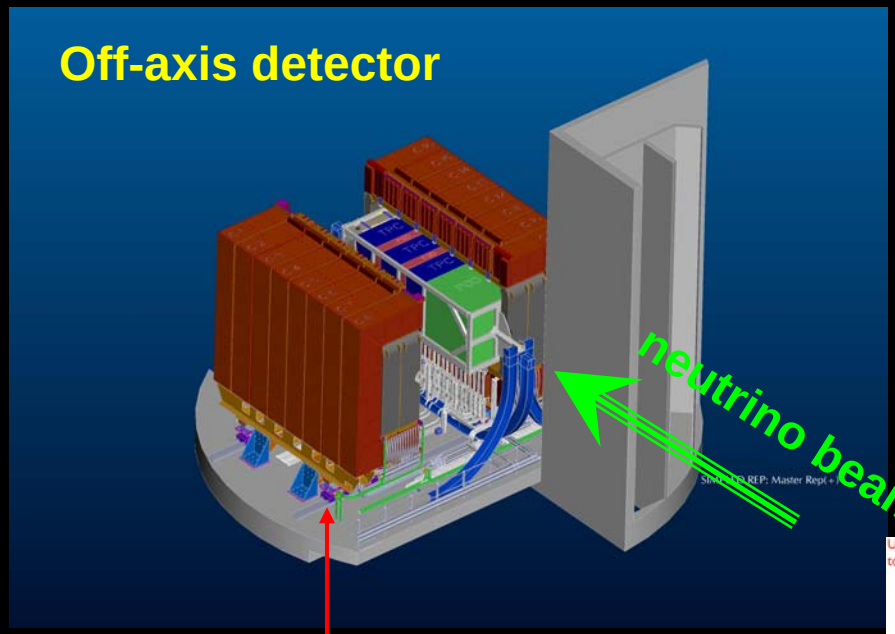
Beam dump installed

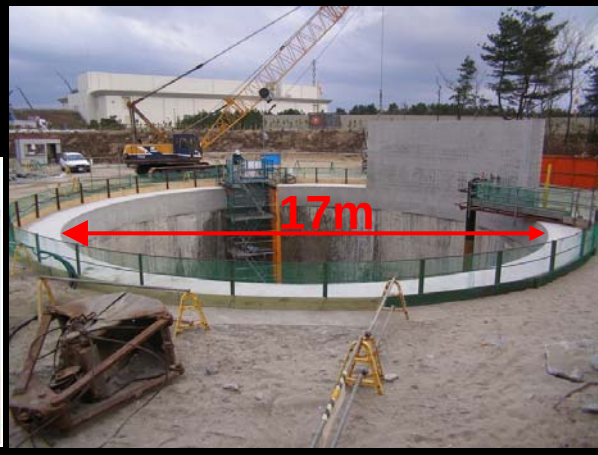
Decay volume completed

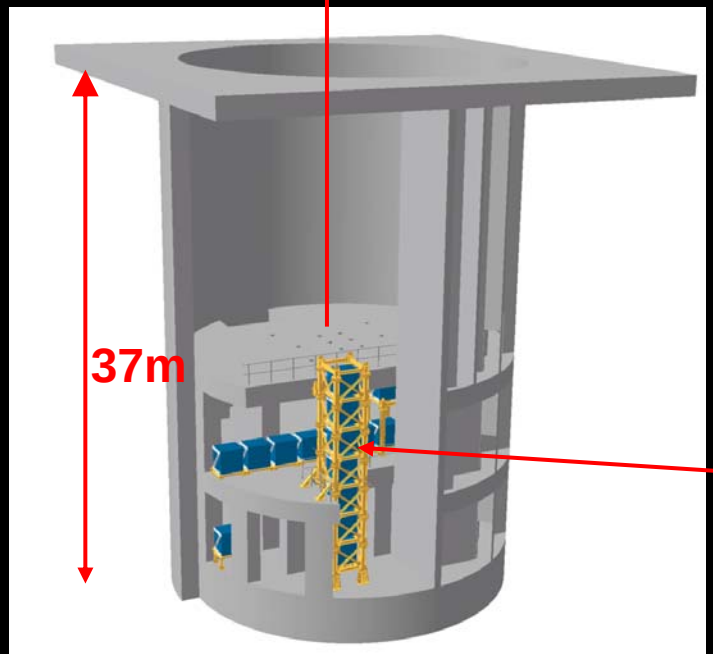
Target station completed

Primary proton line completed

The near detector: ND280

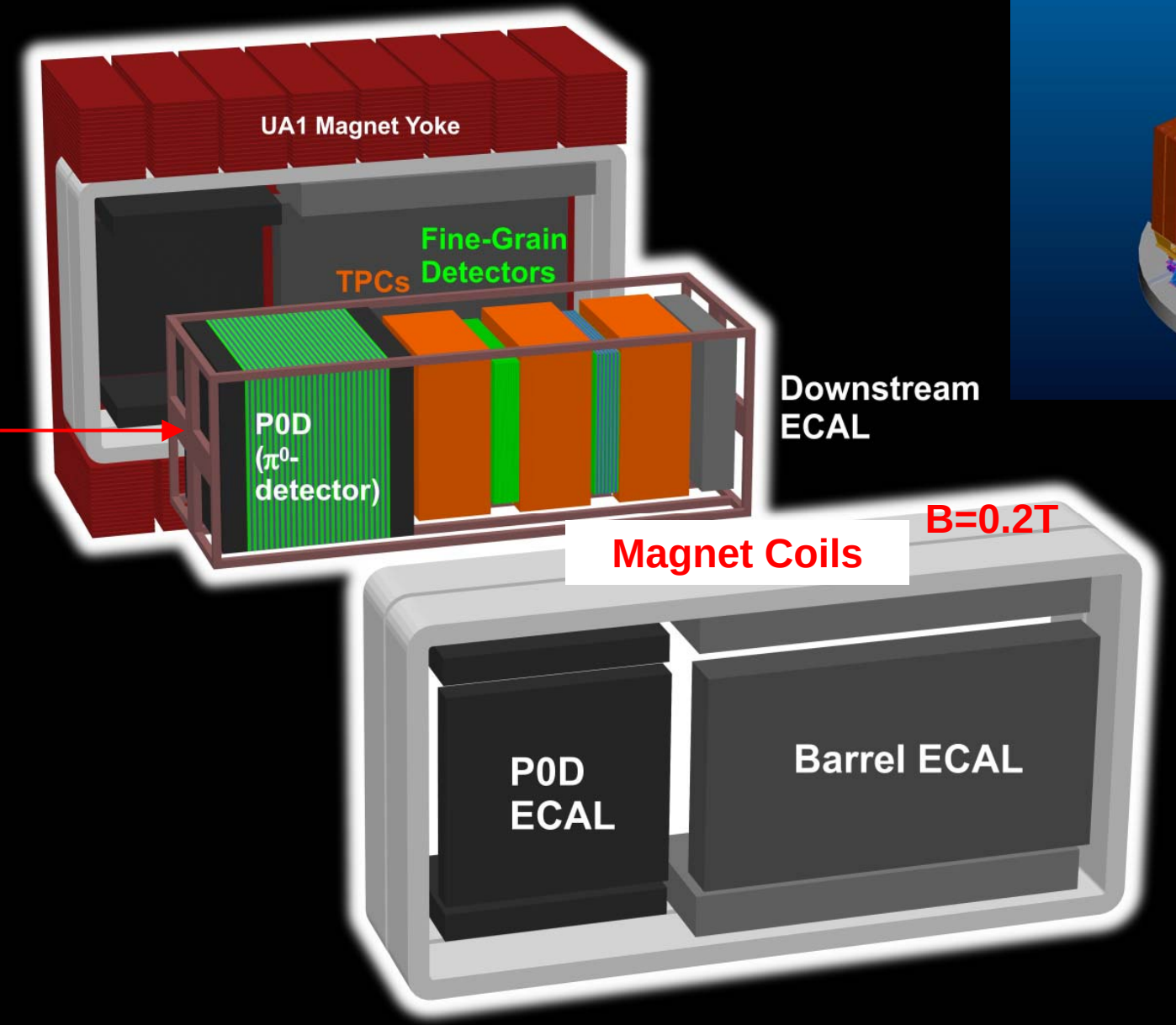


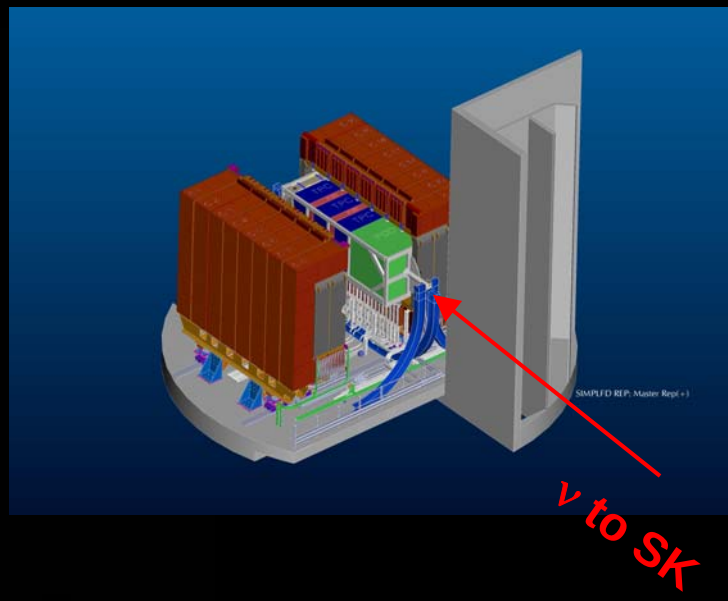




On-axis Detector
INGRID

The off-axis detector

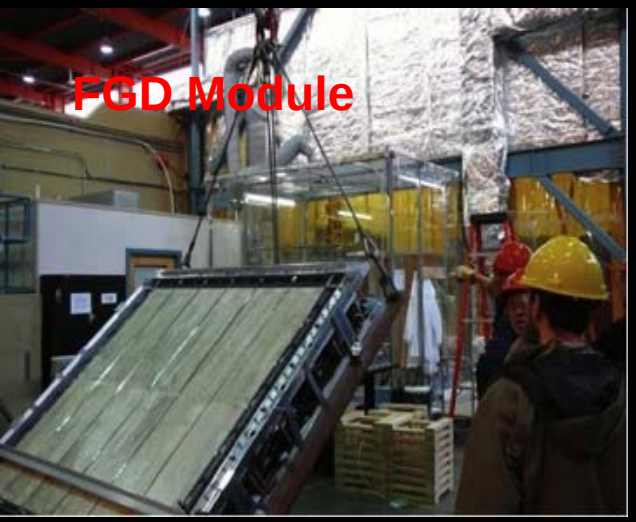


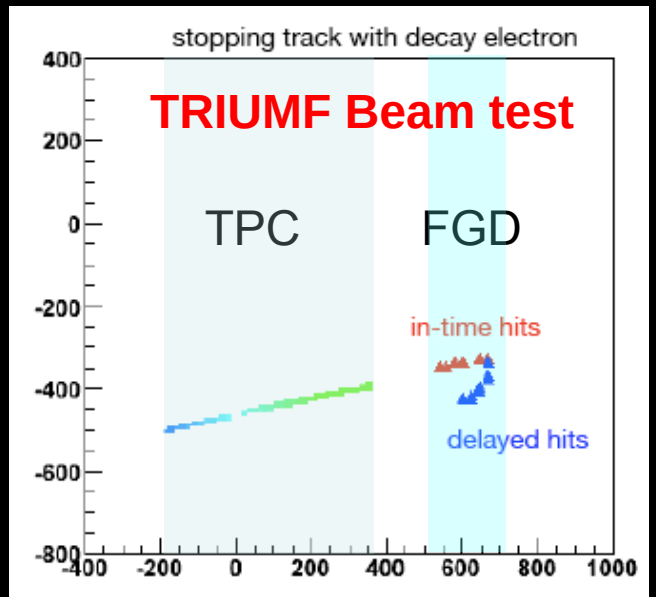


- Instrumented volume: 3.5m x 3.5m x 7.0m
- POD optimized for NC π^0
- Tracker optimized for CC events
- ECAL on 5 sides
- Muon ranging: instrumented yoke

Near Detector subsystems

P0D module

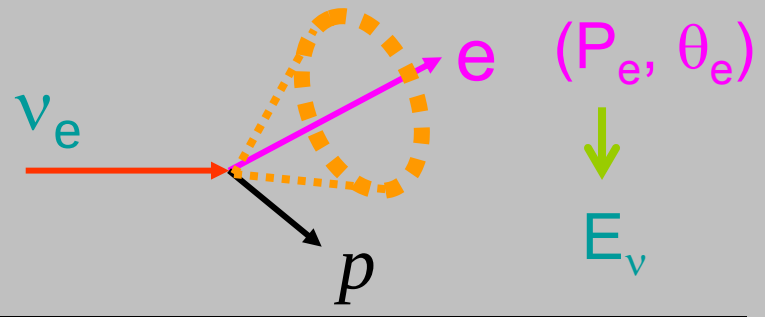


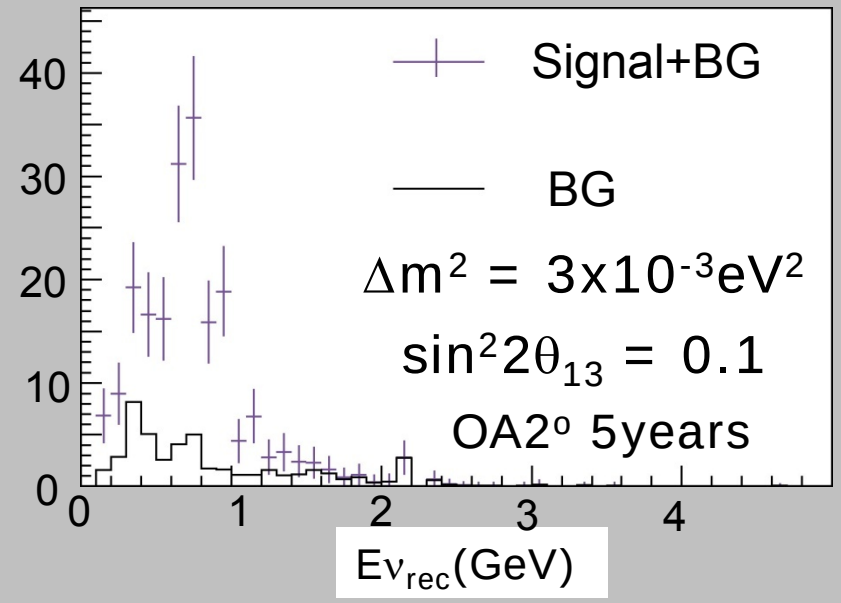


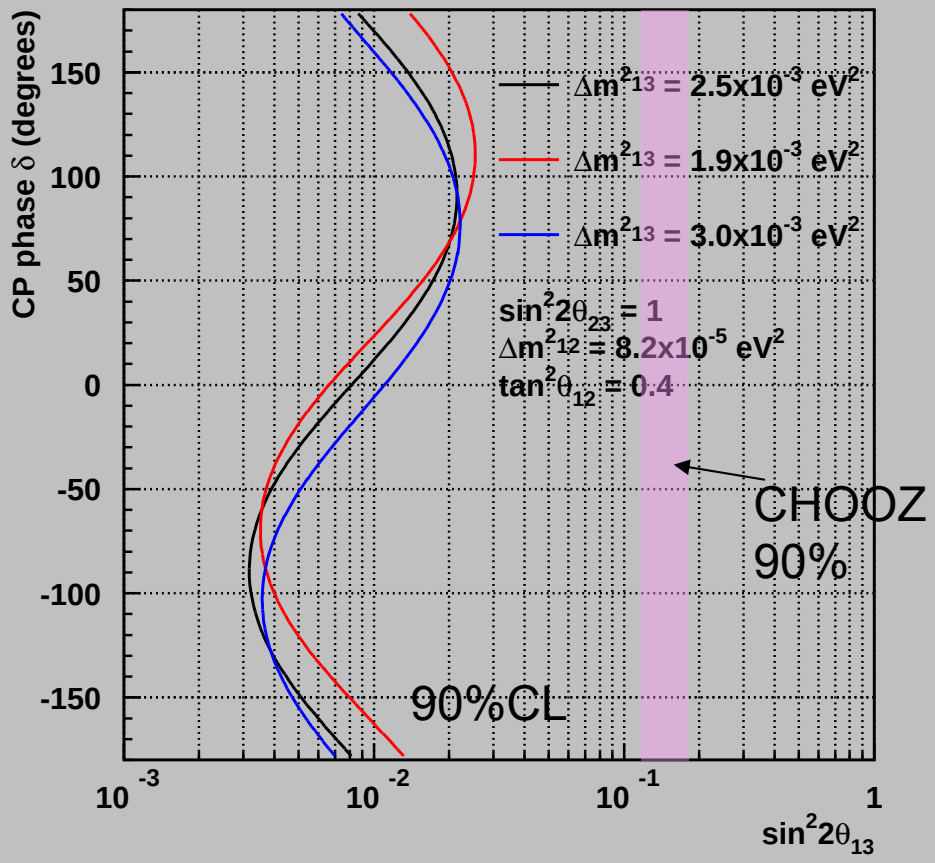
ECAL module

Sensitivity: ν_e appearance

Discovery of ν_e appearance (θ_{13},Δm_{13})



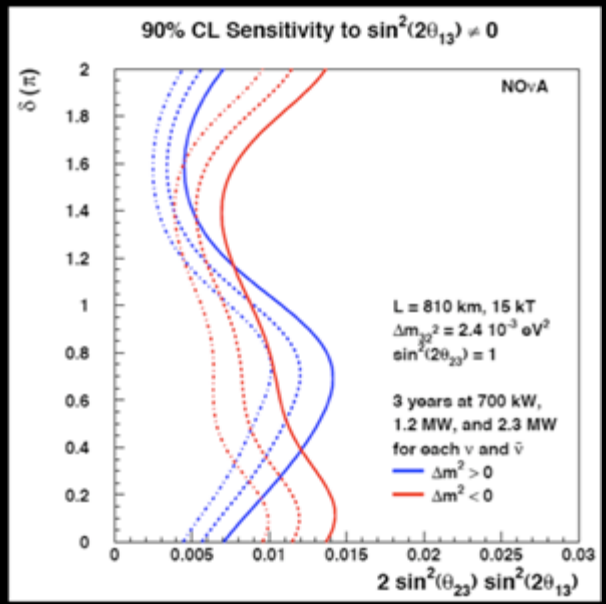




>10 times improvement from CHOOZ

NOvA

- 180 members from 28 institutes, mainly American
- Off-axis, 810kM
- NuMI beam upgrade to 700kW: $51M
- Liquid scintillator in 4cm x 6cm cells
- 14kton far detector: $152M+$60M enclosure
- 222ton near detector: $10M+$5M enclosure
- Funded in FY09 budget, ground breaking in far site starts 1st May
- First data (2.5kton) 2012
- Full detector 2014



Where do we go from there?

- J-PARC plan for 1.7MW before 2015
- Various FNAL power upgrade scenarios including Project-X

- However technical feasibility must be demonstrated, funding nowhere near assured, plus US long-term funding instability problem

- Should CERN keep superbeam option open for Europeans to be able to regain leadership and profit from scientific opportunities that may arise?