# Status T2K experiment

On behalf of UniBe, UniGe and ETHZ groups

André Rubbia (ETH Zürich)

CHIPP Plenary meeting

**Oct 15-16 2007, PSI, Villigen**

# Long baseline neutrino experiments

- Study neutrino flavor oscillation at baseline L and neutrino energy E

Weak-eigenstates

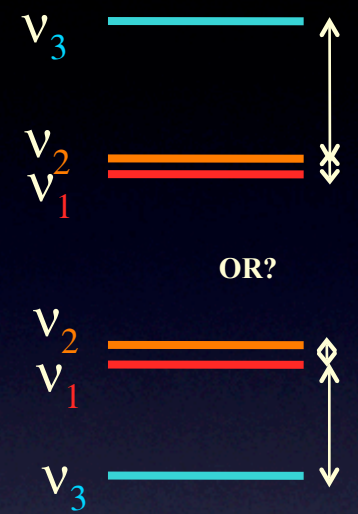
$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = \begin{pmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{\mu 1} & U_{\mu 2} & U_{\mu 3} \\ U_{\tau 1} & U_{\tau 2} & U_{\tau 3} \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

Mass-eigenstates

$$U = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix} \begin{pmatrix} c_{13} & 0 & s_{13}e^{-i\delta} \\ 0 & 1 & 0 \\ -s_{13}e^{i\delta} & 0 & c_{13} \end{pmatrix} \begin{pmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

$$= \begin{pmatrix} \sim \frac{\sqrt{2}}{2} & \sim -\frac{\sqrt{2}}{2} & \sin\theta_{13}\, e^{i\delta} \\ \sim \frac{1}{2} & \sim \frac{1}{2} & \sim -\frac{\sqrt{2}}{2} \\ \sim \frac{1}{2} & \sim \frac{1}{2} & \sim \frac{\sqrt{2}}{2} \end{pmatrix}$$

$\sin^2 2\theta_{13} < 0.1$ (90%C.L.)
δ unknown




$\Delta m^2_{23} = +2\ 10^{-3}\ eV^2$

$\Delta m^2_{12} = 8\ 10^{-5}\ eV^2$

$\Delta m^2_{12} = 8\ 10^{-5}\ eV^2$

$\Delta m^2_{23} = -2\ 10^{-3}\ eV^2$

e.g. $P(\nu_\mu \to \nu_\mu) \approx 1 - \sin^2 2\theta_{23} \sin^2\left(\Delta m^2_{32} \frac{L}{4E}\right)$

- The goal of long baseline neutrino oscillation experiments is to precisely measure the mixing matrix and mass differences (squared) and answer to important questions such as:

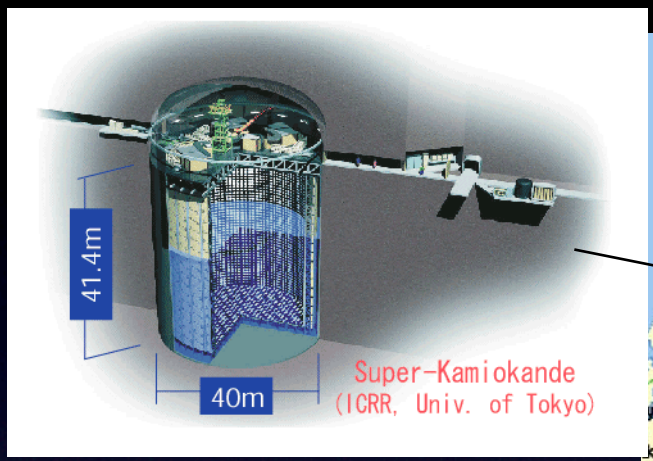
✓ Is $\theta_{23}$ mixing maximal? (present limit: $\sin^2(2\theta_{23}) > 0.92$ at 90% C.L.)

✓ Is $\theta_{13}$ different from zero? (present limit: $\sin^2(2\theta_{13}) < 0.1$ at 90% C.L.)

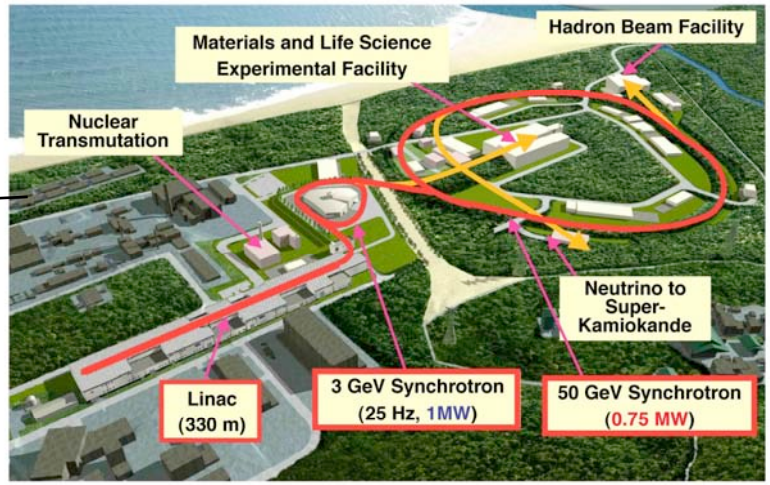
✓ Is there CP violation in the leptonic sector? (i.e. is $\delta \neq 0$?)

✓ Is there normal or inverted hierarchy? (i.e. which is the sign of $\Delta m^2_{32}$?).

# Tokai to Kamioka (T2K)




Far detector : Super Kamiokande


ν beam : J-PARC facility
Japan Proton Accelerator Research Complex

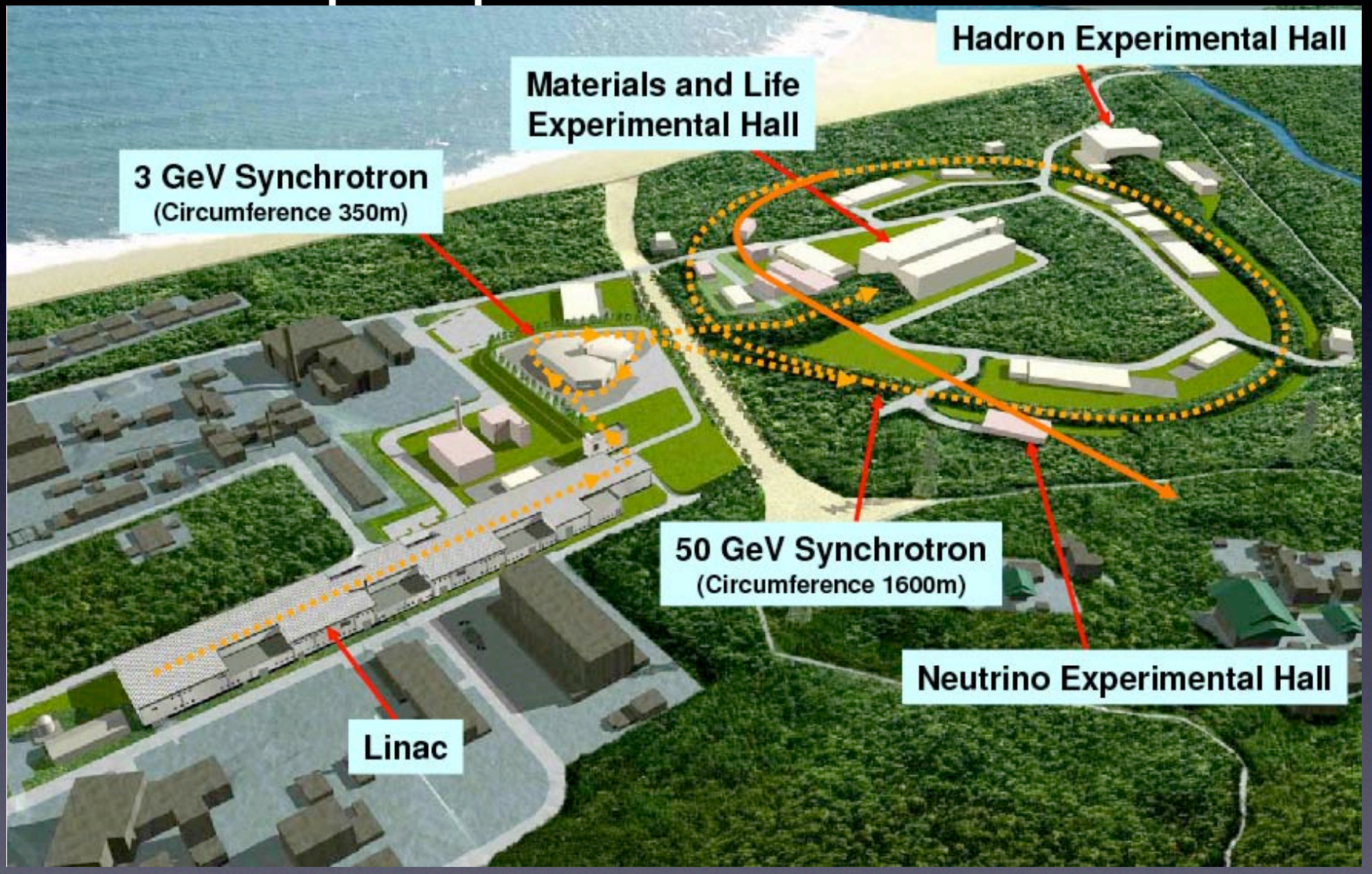
- **2009 Phase I : $\theta_{13}$, $\theta_{23}$, $\Delta m^2_{23}$**
  - J-PARC : 0.75 MW 40 GeV
  - SK-III : 22.5 kT FV, full PMT coverage
- **>2015 Phase II : $\theta_{13}$ , $\delta_{CP}$ ?**
  - J-PARC : 4MW 50 GeV
  - HyperK ?: 1 MT scale ?

Currently 28/62 European institutes,
~175/380 European names

# J-PARC (Japan Proton Accelerator Research Complex)

**Joint Project between KEK and JAEA**

**MW power proton beams at 3 and 50 GeV**



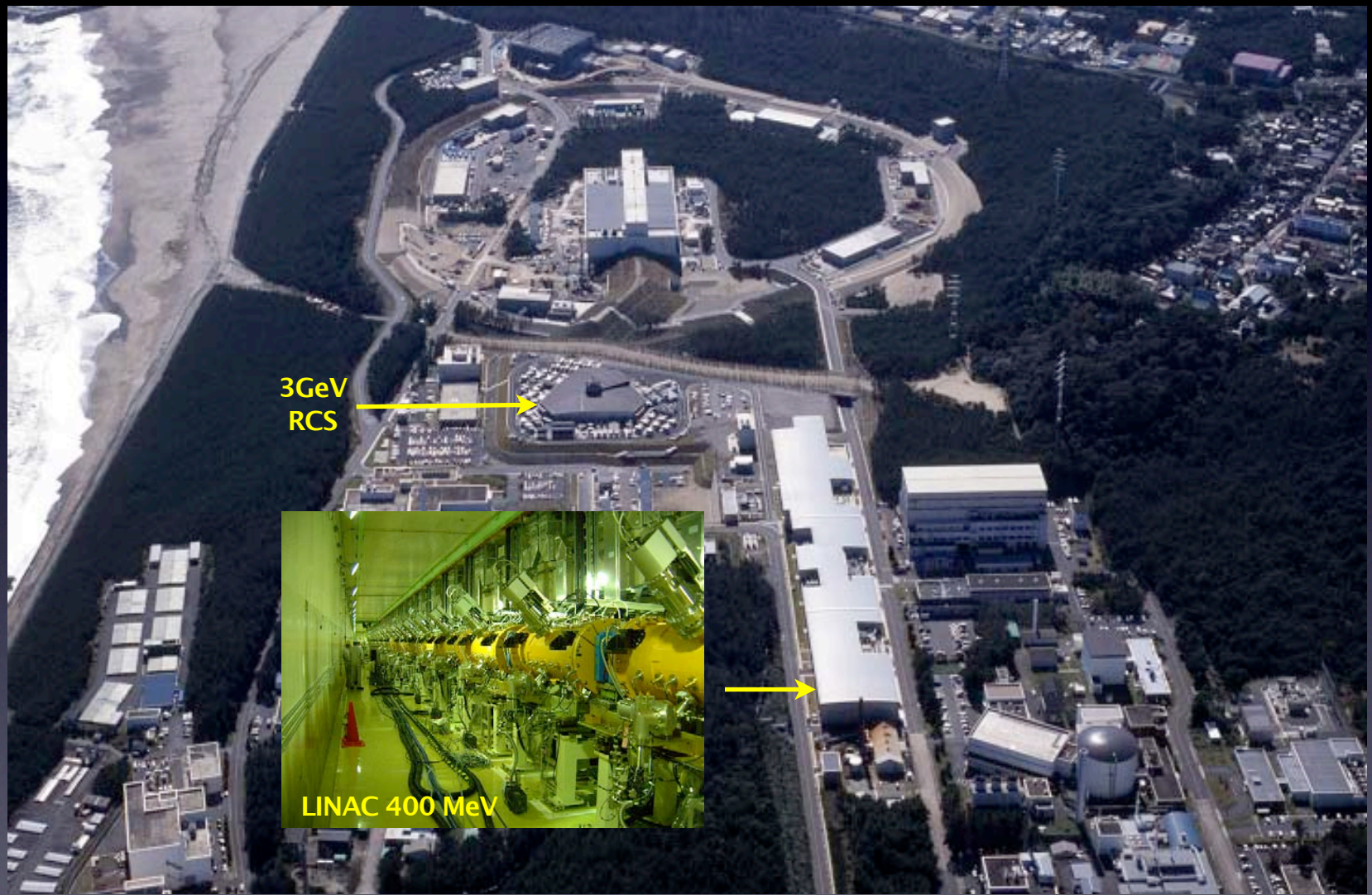
# J-PARC

Nov 2006

# J-PARC

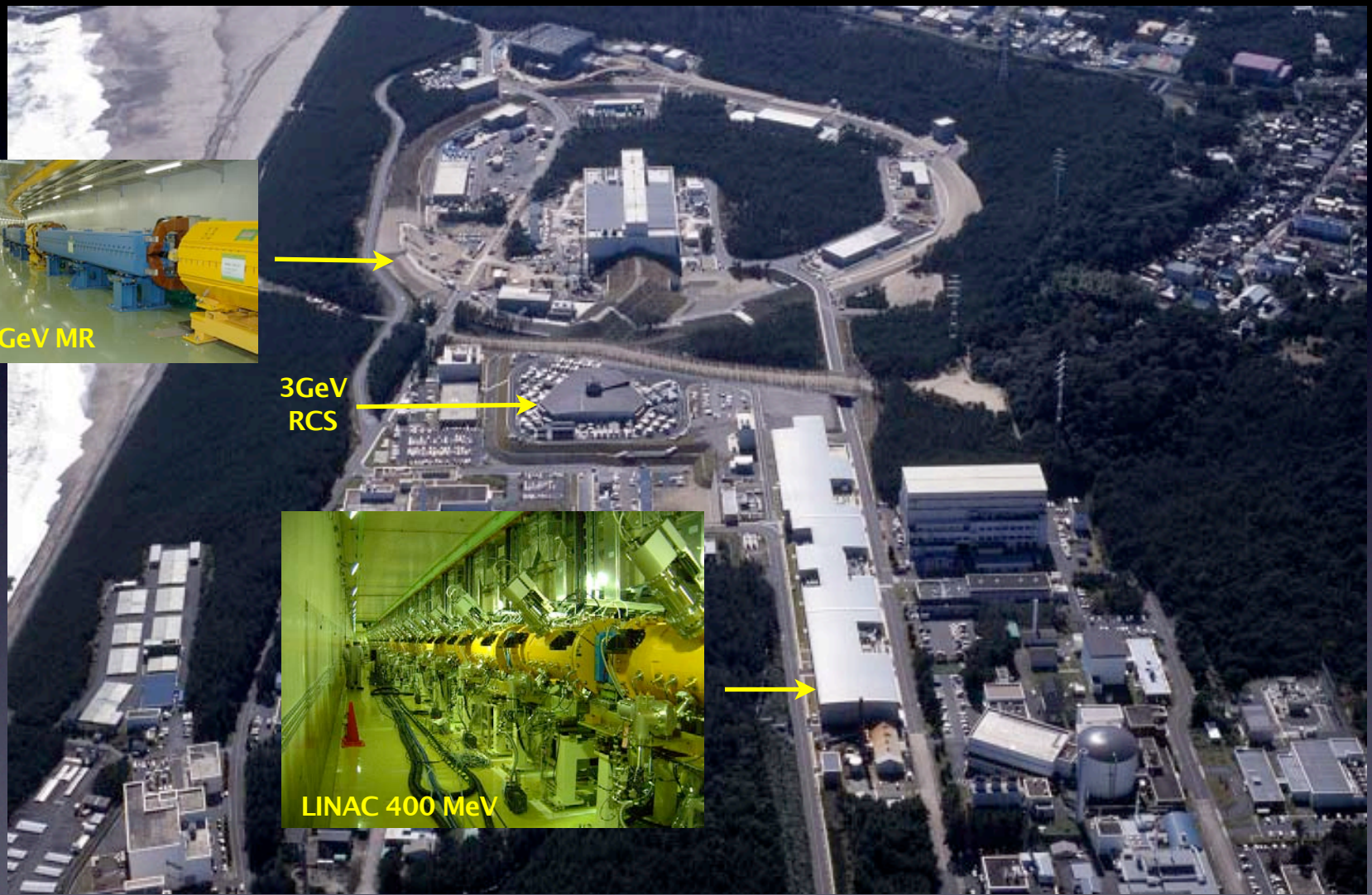

Nov 2006

# J-PARC




Nov 2006

# J-PARC




Nov 2006

# J-PARC



3GeV
RCS


Nov 2006

# J-PARC




3GeV
RCS


Nov 2006

# J-PARC




3GeV
RCS

Target
region


Nov 2006

# J-PARC




3GeV
RCS

Target
region

Beam dump


Nov 2006

# J-PARC





ND280

3GeV
RCS

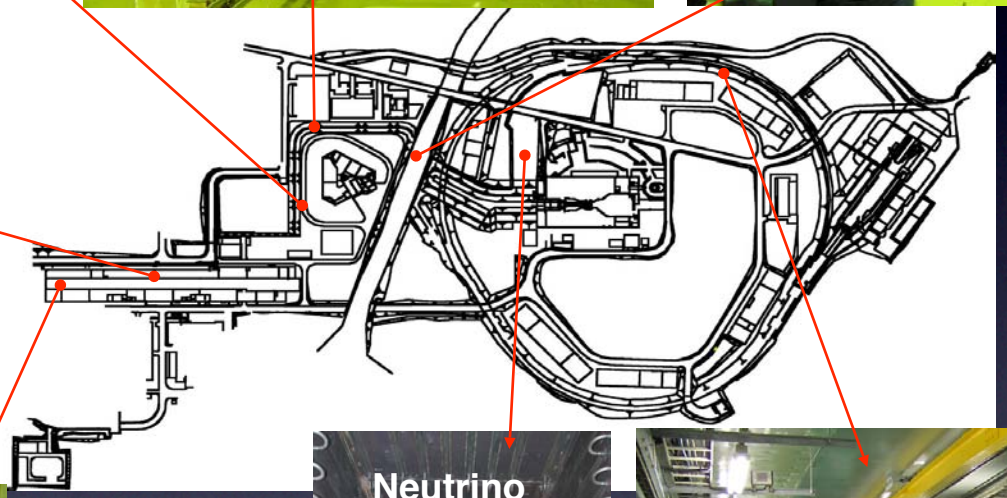
Target
region

Beam dump

Nov 2006

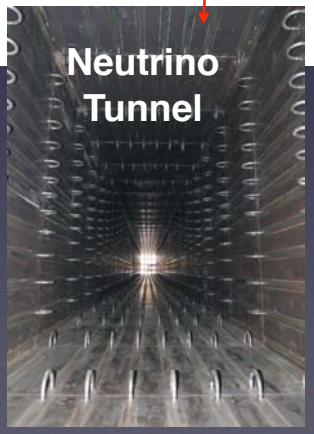




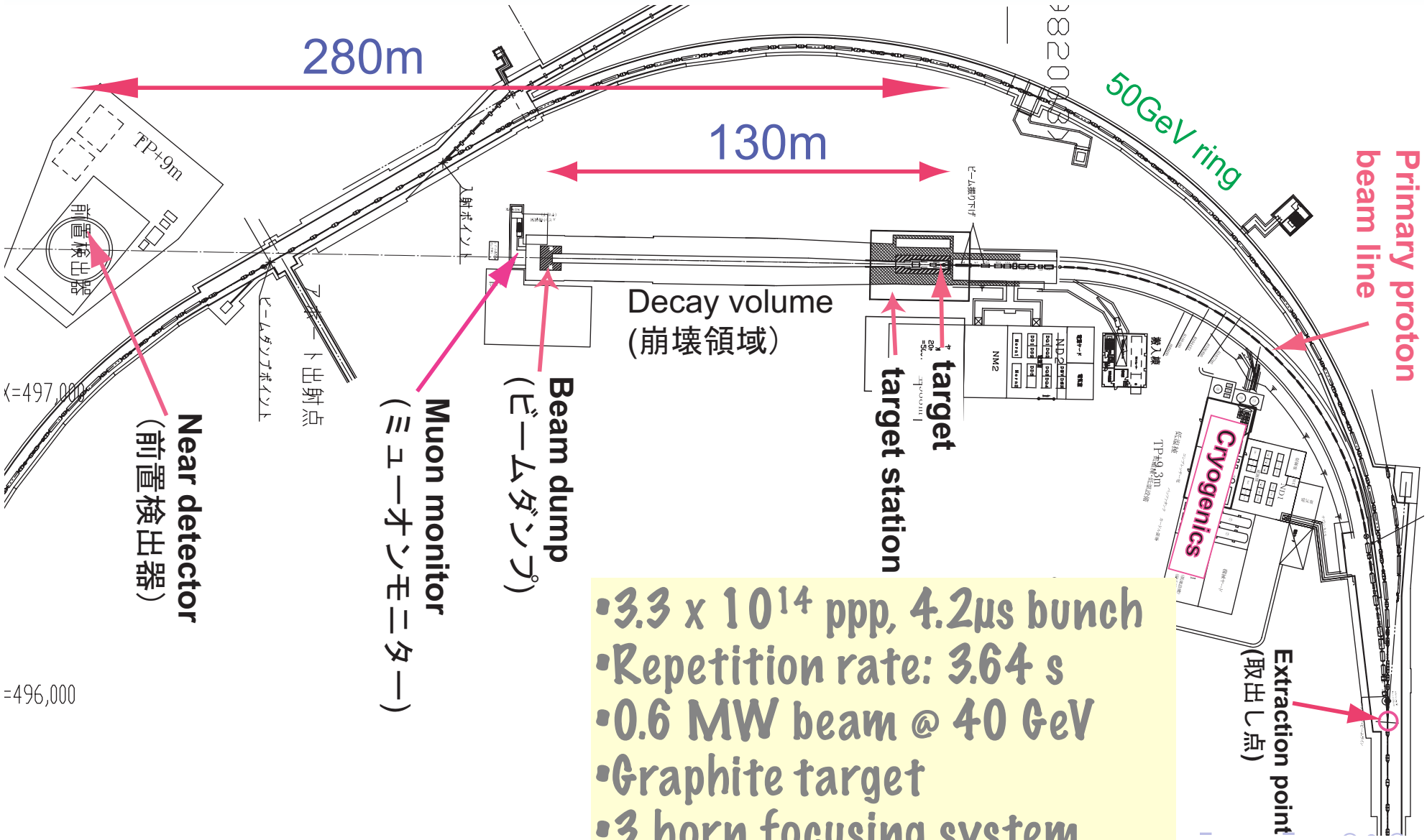


JPARC


Tunnel
Tour




# Neutrino beamline (design for MW)




- 3.3 x $10^{14}$ ppp, 4.2μs bunch
- Repetition rate: 3.64 s
- 0.6 MW beam @ 40 GeV
- Graphite target
- 3 horn focusing system

# Future neutrino beams worldwide

**JHEP 0611:032,2006**

| | JPARC | | FNAL | | CERN | | |
|---|---|---|---|---|---|---|---|
| | design | upgrade | w/o PD | w PD | CNGS dedicated | CNGS' | CNGS+ |
| Proton energy $E_p$ | 40 GeV/c | | 120 GeV/c | | 400 GeV/c | | |
| $ppp(\times 10^{13})$ | 33 | $> 33$ | 9.5 | 15 | 4.8 | 7 | 14 |
| $T_c$ (s) | 3.64 | $< 3.64$ | 1.6 | 1.467 | 6 | 6 | 6 |
| Efficiency | 1.0 | 1.0 | 1.0 | 1.0 | 0.55 | 0.55 | 0.83 |
| Running (d/y) | 130 | 130 | 230 | 230 | 200 | 200 | 200 |
| $N_{pot}$ / yr $(\times 10^{19})$ | 100 | $\simeq 700$ | 120 | 200 | 7.6 | 11 | 33 |
| Beam power (MW) | 0.6 | 4 | 1.1 | 2.0 | 0.3 | 0.4 | 1.2 |
| $E_p \times N_{pot}$ $(\times 10^{22}$ GeV×pot/yr) | 4 | 28 | 14.4 | 24 | 3 | 4.4 | 13.2 |

*FNAL ≈ 5x MINOS beam (post Tevatron)*

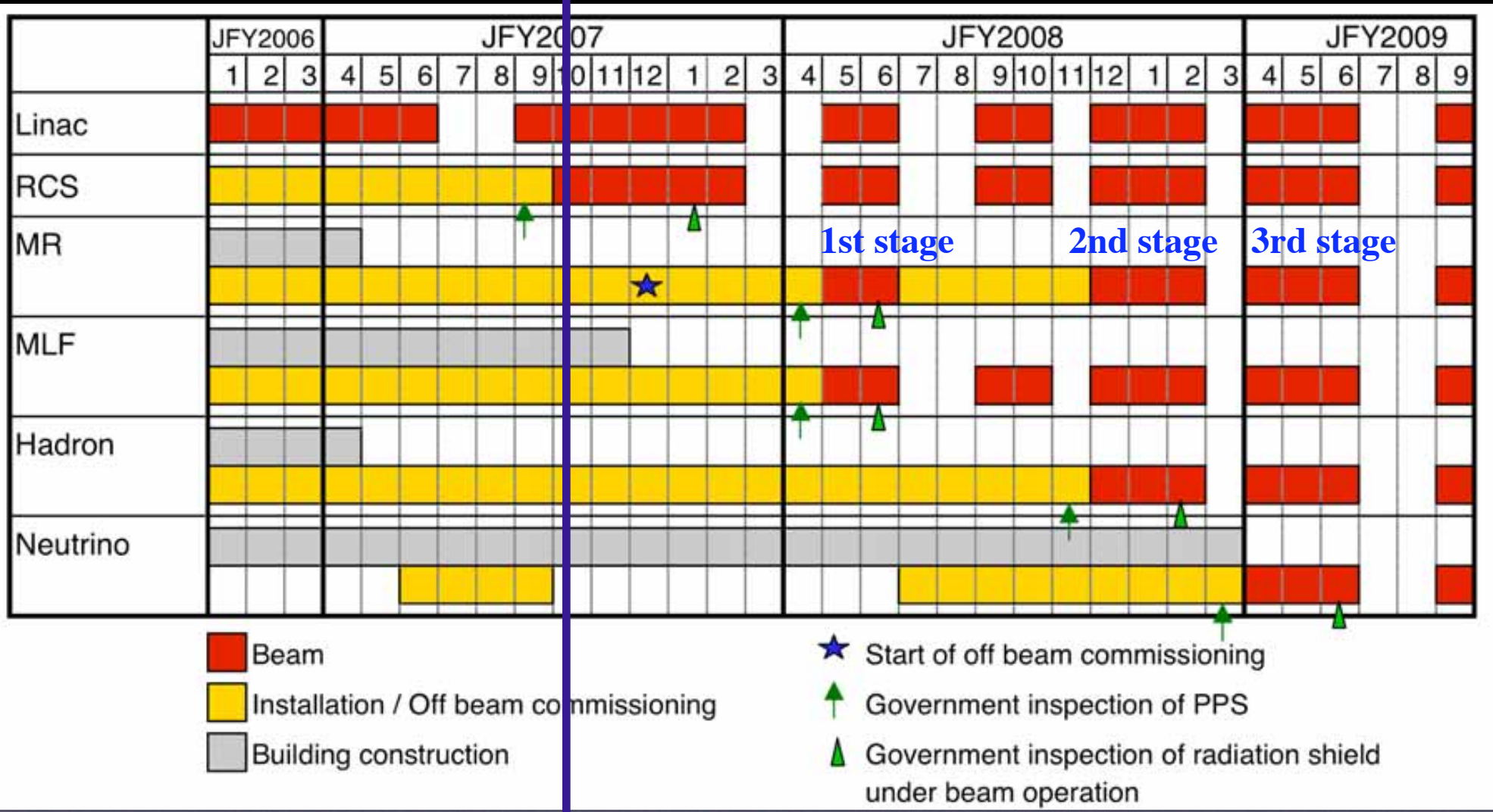
*New LHC injectors >2016 ?*

*CNGS dedicated ≈ 2x OPERA beam (2007-2011)*

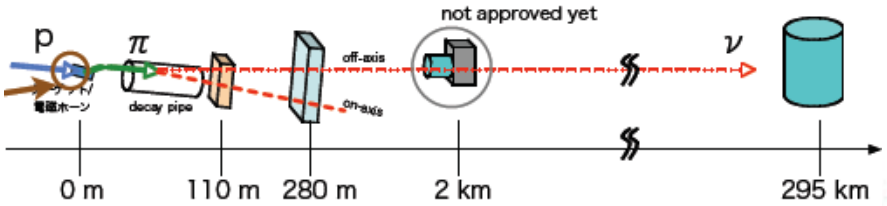
T2K phase 1 goal: 1e21 pot/year

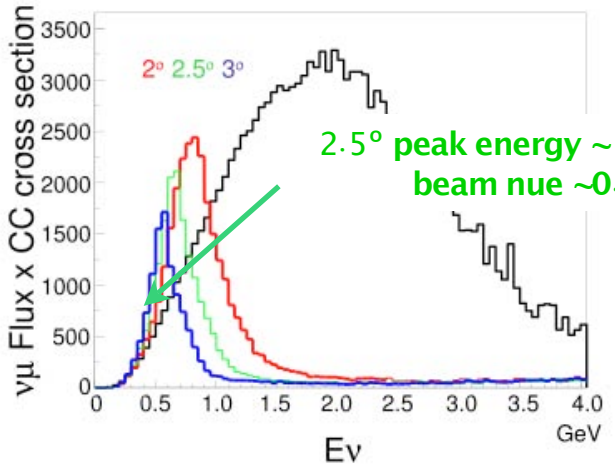
Upgraded beam: 7e21 pot/year (28 e22 GeVxpot)

# JPARC commissioning schedule



# T2K main measurements

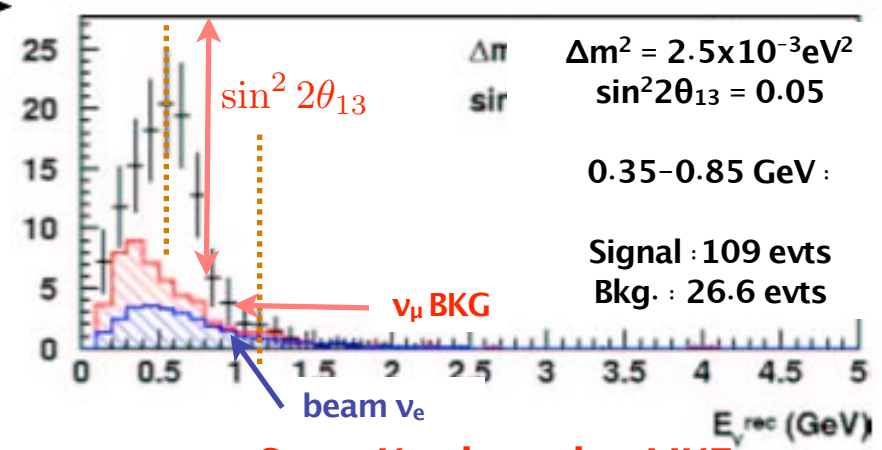


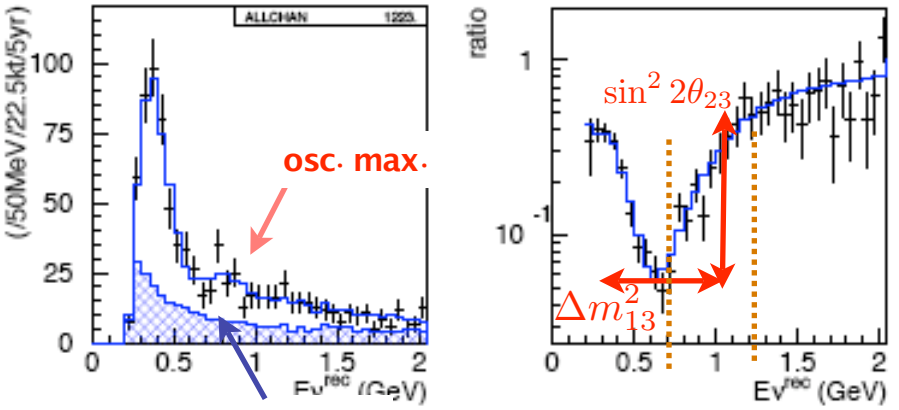

2.5° peak energy ~650 MeV
beam nue ~0.5%

## $U_\mu \rightarrow \nu_e$

SuperK selected e-LIKE evts




SuperK selected μ-LIKE evts




## $U_\mu \rightarrow \nu_\mu$

- Appearance

$$\sin^2 2\theta_{13} > 0.01$$

- Disappearance

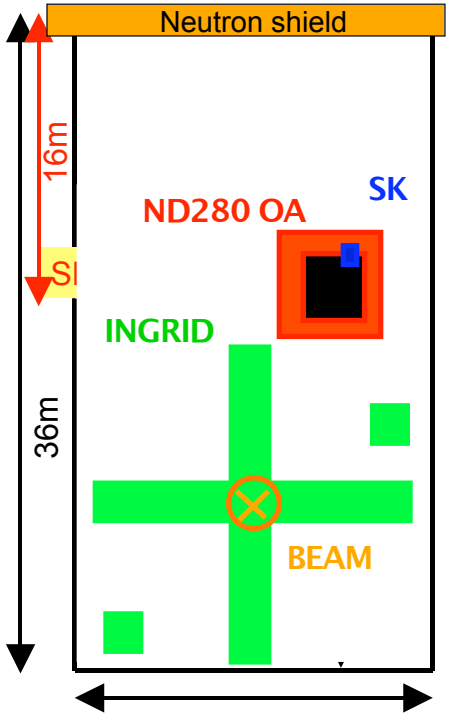
$$\delta(\sin^2 2\theta_{23}) \approx 0.01$$

$$\delta(\Delta m^2_{13}) < 10^{-4}\ \mathrm{eV}^2$$

# ND280 Near Detectors

- To be measured before oscillation: Beam flux, Beam νe contamination, non-QE background
- Near detector tasks :
  - SuperK νe background < 10%
  - νμ event normalisation < 5%
  - Energy scale <2%
  - Beam linear distortion < 20%
  - Width < 10%
  - non-QE/CCQE at 5-10%

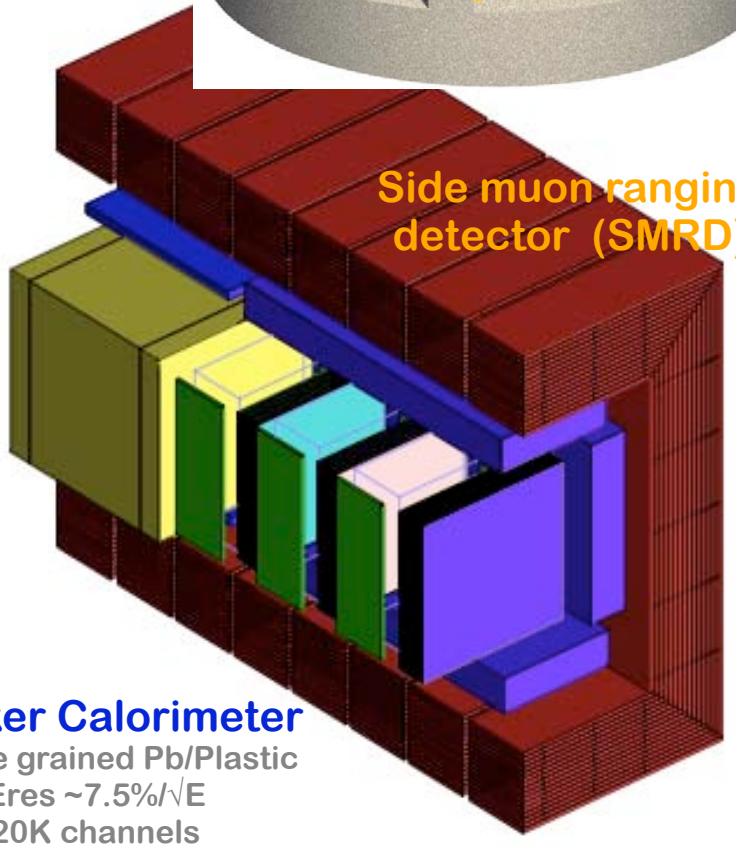
**ND280 Pit**




**UA1/NOMAD magnet**
B=0.2 T

**3 TPC modules**
MicroMegas pads
Position resolution < 0.8 mm
Mom resolution to 1GeV <7-8%

**2 Fine Grained 2x1.3t target detectors (FGD)**
FGD1(C): X-Y plastic
FGD2(H20): X-Y plastic+passive water target
8k channels



**Side muon ranging detector (SMRD)**

**Tracker Calorimeter**
X-Y fine grained Pb/Plastic
Eres ~7.5%/√E
20K channels

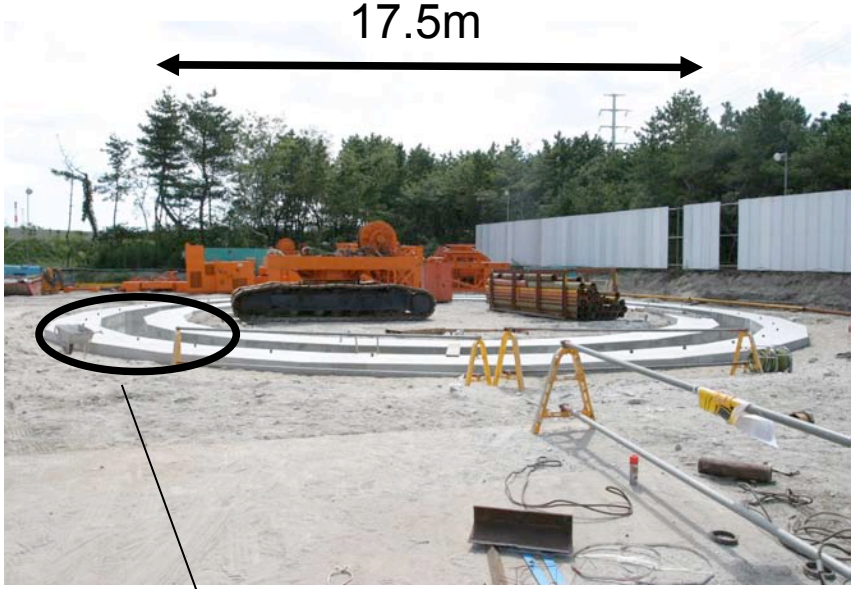


11

# ND280 pit area

Status of September 19

- Guide wall was completed
- Frame is being build
- Excavation for wall is being prepared




Guide wall to install frames and make the concrete wall

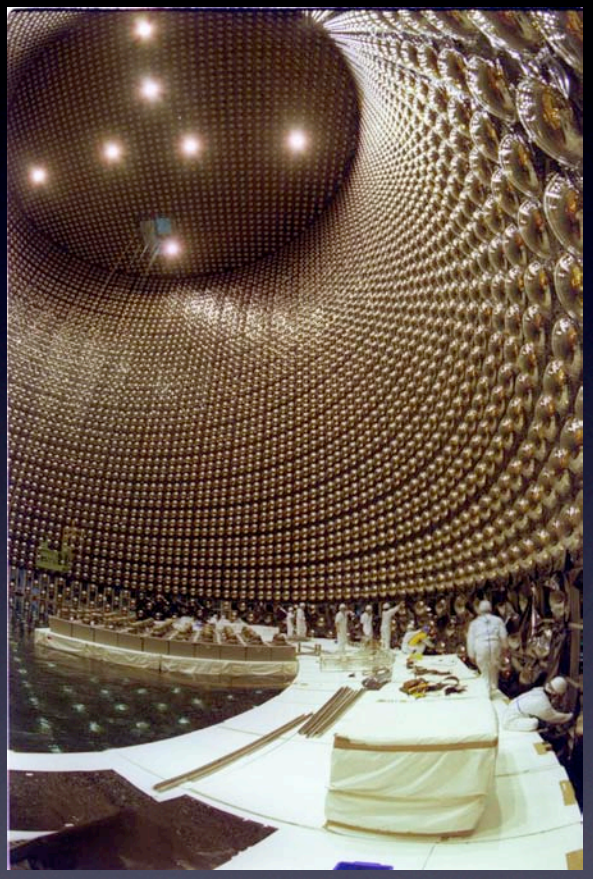
End of civil engineering: March 2008

2007/Sep28 ND280 Facility

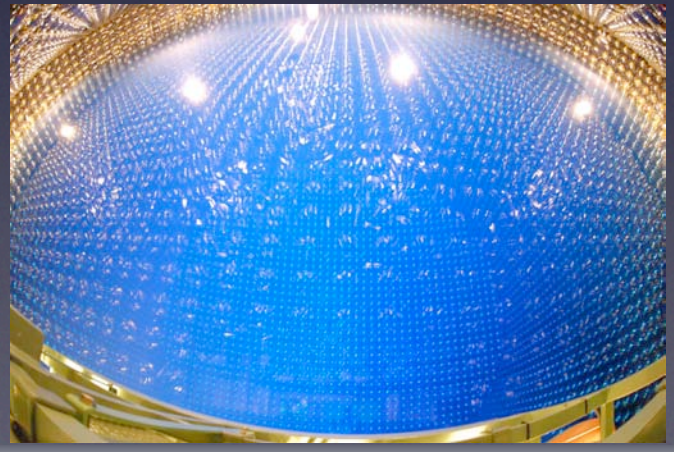
# Far detector: SK fully reconstructed (October 2005 – April 2006)

~6000 ID PMTs were produced from 2002 to 2005 and were mounted from Oct.2005 to Apr.2006.

All those PMTs were packed in acrylic and Fiberglass Reinforced Thermoset (FRP) cases.

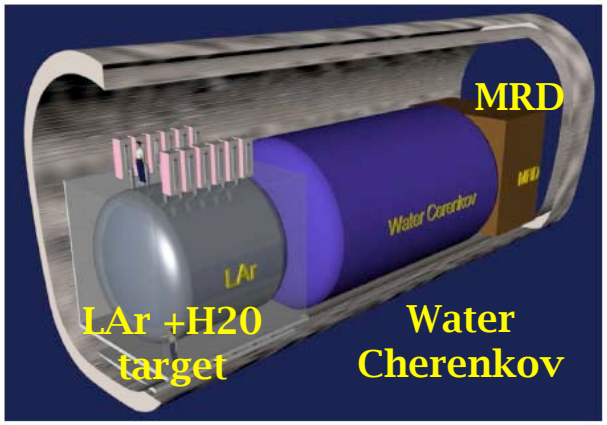


Mount PMTs on a floating floor.

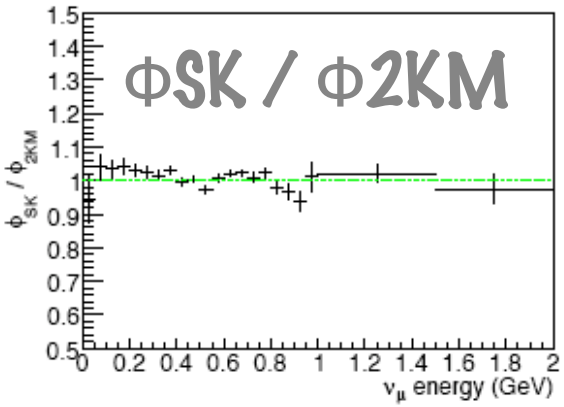


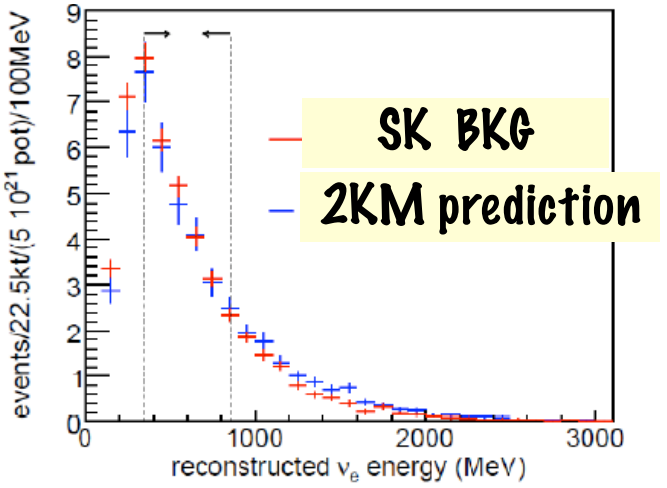
Pure water was supplied and SK-III data taking has been running since July 11, 2006.
+ New readout electronics (Summer 2008)

# 2km detectors (LOI)




- Strengthen prediction of far detector flux through measurement (~2 km away) using :
  - Almost same beam flux as far detector
  - Same target material
  - Same detector technology and reconstruction analysis
- Check ND280+NA61 prediction before oscillation
- Combine ND280+2kM measurements
  - Reduce further the systematic errors
  - Understand better the ve backgrounds




**Submitted to JPARC PAC and US DOE (CD0 approved)**



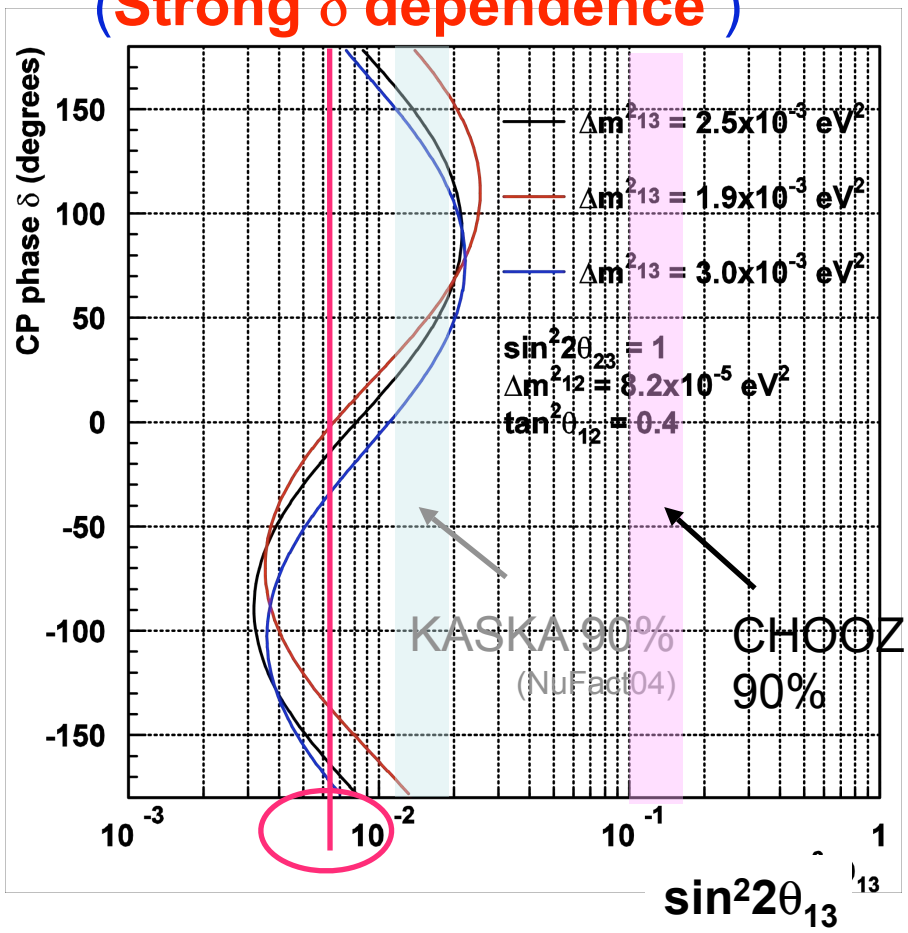
14

# T2K Physics Sensitivity (Phase I)

5x $10^{21}$ pots

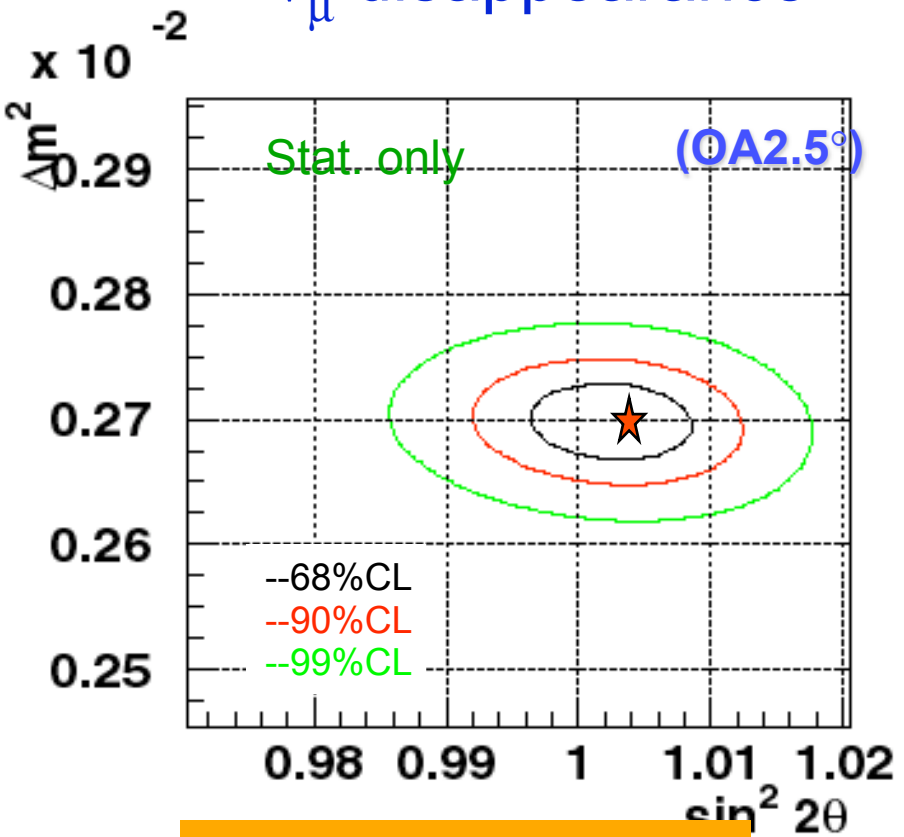
## $\nu_e$ appearance

(**Strong $\delta$ dependence** )




**>10 times improvement from CHOOZ**

## $\nu_\mu$ disappearance




Goal

$\delta(\sin^2 2\theta_{23}) \sim 0.01$

$\delta(\Delta m^2_{23}) \sim < 1\times10^{-4}$



15

# Swiss contributions to T2K

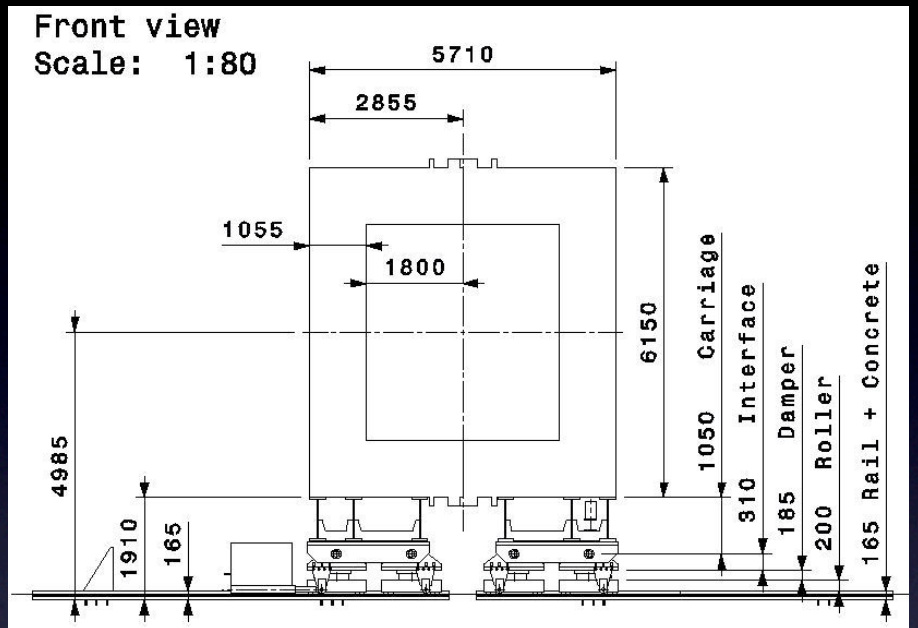
UniBe, UniGe, ETHZ: in total ≈15 physicists, ≈8 PhD students, ≈8 engineers/technicians

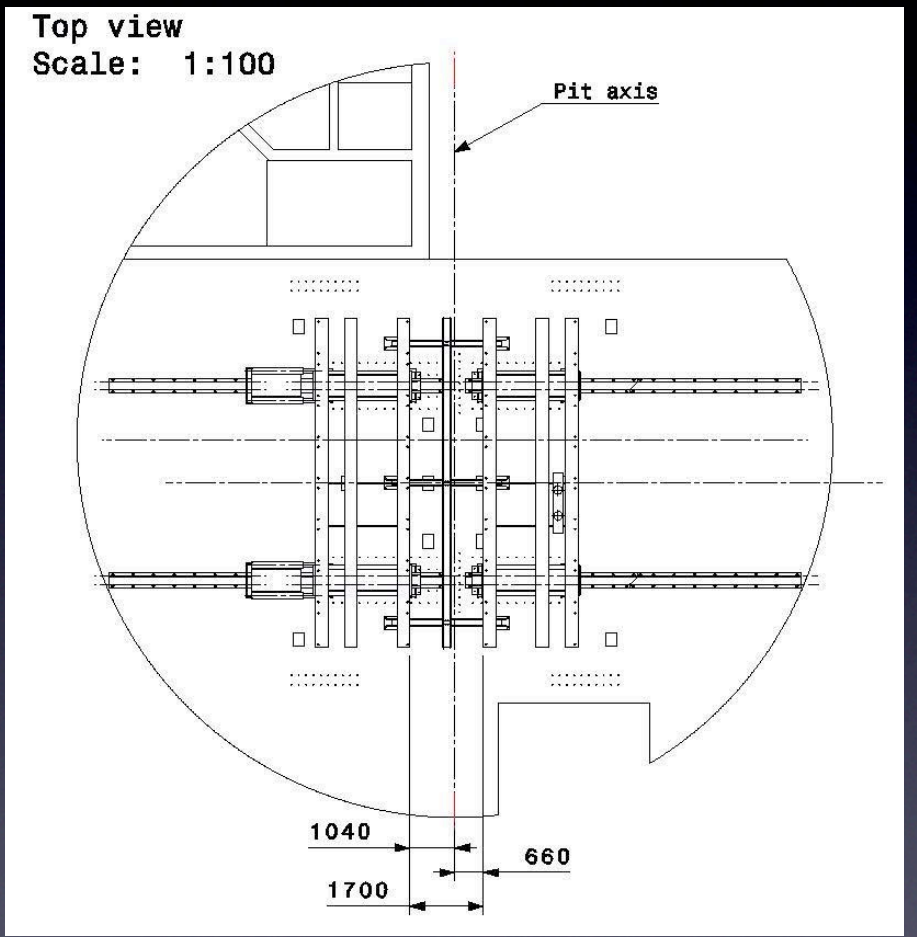
- ND280 magnet project (refurbishing @ CERN, shipping from CERN to Tokai, installation @ Tokai, operation and calibration @ Tokai)
- Contributions to ND280 TPC
- 2km LOI
- Liquid Argon TPC R&D
- NA61 @ CERN (see specific talk)

# Magnet related tasks

1. Engineering of magnet (including seismic analysis - very different)
2. Dismantling yokes and refurbishing yokes, coils & carriages at CERN
3. Shipment of yokes, coils and carriages to Tokai
4. New rails, rollers, damping springs & moving system (parts from HERAB)
5. New power supply and power cables
6. New slow control system
7. New cooling-water system
8. Re-mounting of yokes
9. Yokes installation including new alignment constraints (SMRD)
10. Coils installation including new preparation for ECAL support
11. Finish installation
12. Magnet test & pre-commissioning
13. Field map measurement

# Magnet engineering and integration



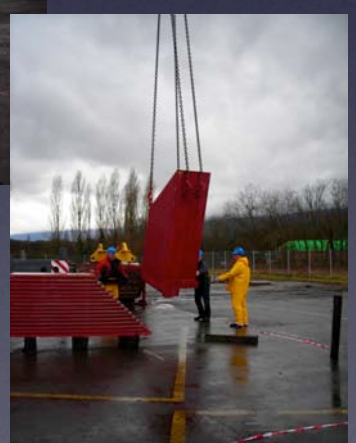




- Several fixes & updates
- Feed-back from seismic analysis
- New rails
- New MMS
- Carriage fixing
- Position in pit
- ...

# Dismantling for shipment

Aluminium protection

Directly connected with bolts



# Coils pressure & electrical tests (Blg184)


Tested to 25 bars, up to 1.35 kV for 30s

# Magnet refurbishing e.g. yokes...

16 yokes
53 tons each

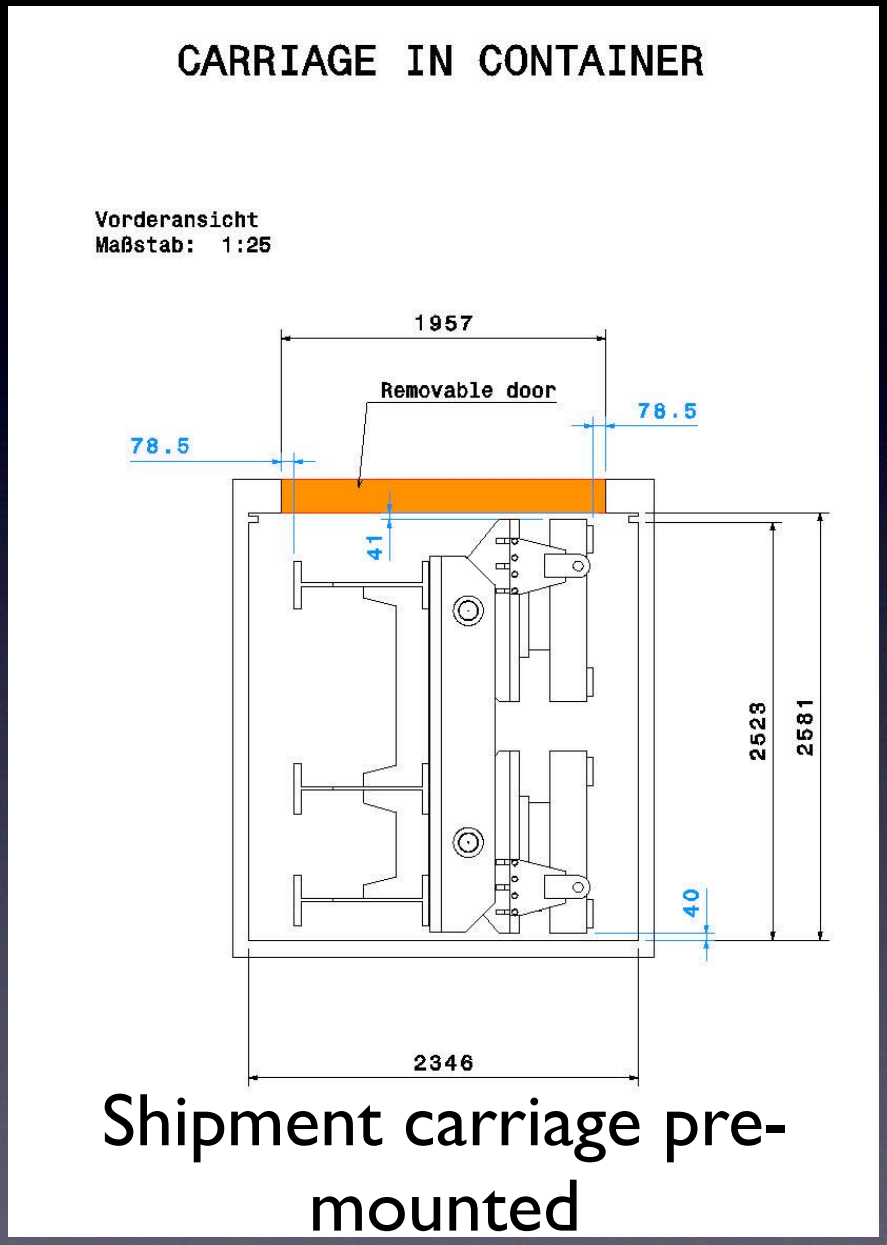


# New magnet moving system

Rollers

Interface

Carriage + interface




Shipment carriage pre-mounted

| | Title: ND280 magnet: List of components | Page: | 1 of 50 | |
|---|---|---|---|---|
| | | Rev: | 0.4 | Date:08/22/07 |
| | | Author: | AG | |
| | | Checked: | AR | |

# Shipment from CERN to Tokai

ND280 magnet:
List of components

| | | | | | |
|---|---|---|---|---|---|
| 0.4 | Fix small typos | AR | AR | | 8/30/07 |
| 0.3 | Update drawings | AG | AR | | 08/22/07 |
| 0.2 | Update drawings | AG | AR | | 08/15/07 |
| 0.1 | First Issue | AG | AR | | 08/02/07 |
| REV | DESCRIPTION | AUTHOR | CHK | | DATE |

ND280 magnet installation (8/30/07)

## Appendix A: Magnet Yokes and Accessories to handle yokes

-) Yoke: 16 Pieces
  -) Yoke dismantled

-) Lifting Jig:

  -) Lifting Jig Beam 1 Piece
  -) Connection Lifting Jig – Crane 2 Pieces
  -) Connection Lifting Jig – Yoke 4 Pieces

-) Hydraulic Jack 4 Pieces

-) Mechanical Jack with support ( Detonated view)

  -) Mechanical Jack with support 12 Pieces

-) Box with Bolts 1 Piece

## Appendix B: Carriages and Magnet Moving System (MMS)

-) Carriage: 2 Pieces

-) Interface to Carriage 8 Pieces

-) Rail 8 Pieces

-) Rollers with Hydraulic damper 8 Pieces

-) Hydraulic movers 2 Pieces

-) Control unit 1 Piece

-) Floor fixing Carriage 4 Pieces

-) Carriage fixing Floor 4 Pieces

-) Leiterrahmen 1 Piece

## Appendix C: Aluminium coils and Accessories to lift coils

-) External Coil 2 Pieces

-) Internal Coil 2 Pieces

-) Mechanism to lift coils:

  -) Beam to lift coils 1 Piece
  -) Connection for Crane 2 Pieces
  -) Connection for Coil 4 Pieces

-) Bus Bar Several Pieces

## Appendix D: Accessories for Yoke Alignment

-) Alignment System:

  -) HEB220 for alignment 1 Piece
  -) Pedestal 3 Pieces
  -) Alignment support 3 Pieces

## Appendix E: Accessories for Yoke Rotation

-) System to Rotate Yoke:

  -) Connection Yoke – Crane 1 Piece
  -) Bottom Plate 1 Piece
  -) Support over Blocks 1 Piece
  -) Support Yoke – System 4 Pieces
  -) Rotation Support: 1 Piece
  -) Connection Yoke – System 1 Piece
  -) Support over Bottom Plate 1 Piece
  -) Iron Block 3 Pieces
  -) L to fix Blocks 1 Piece
  -) U to fix Blocks 4 Pieces
  -) Threaded Rods 4 Pieces

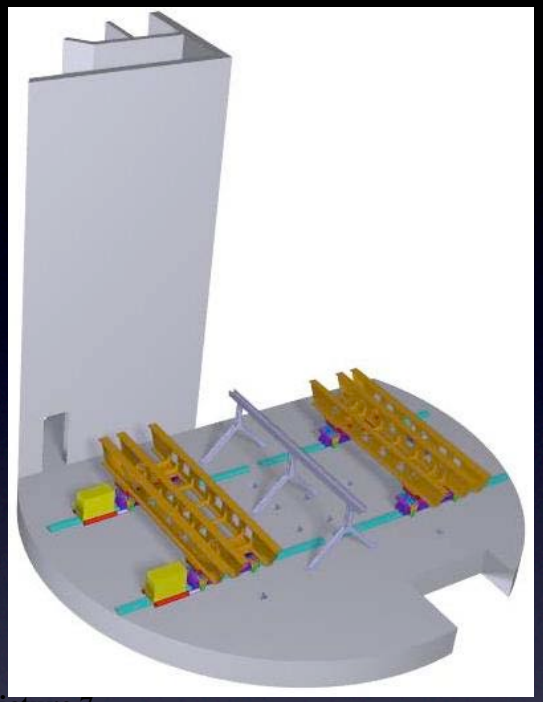
≈ 5 MCHF capital value
≈40 x 40’ containers
cost ≈ 500kCHF

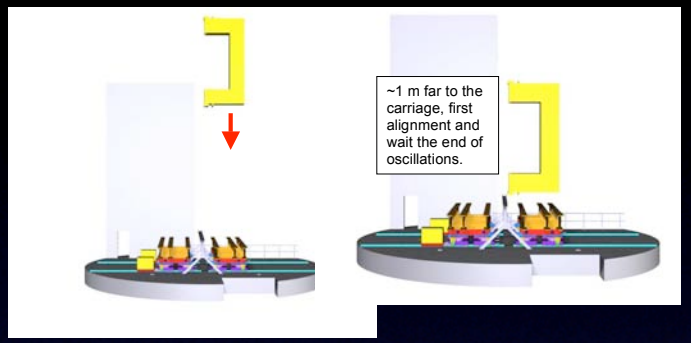
Invitation to tender (CERN FI) ⇒ October 29th 2007

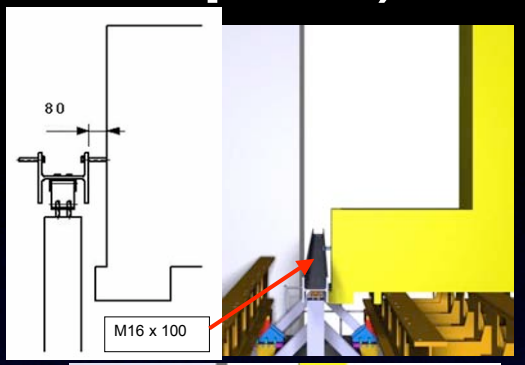
# Magnet installation

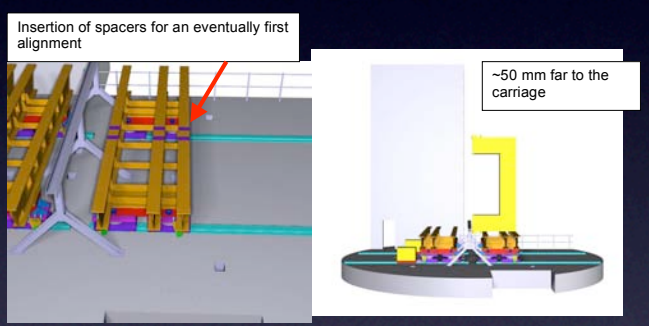
- 40 pages document
- Several meetings with Japanese installation companies
- Plan, timescale and cost estimate worked out (≈800kCHF)
- Possible minor modifications after C reassembly tests, sag measurement and modal frequency meas'ment @ CERN
- Next steps:
  - Tender process: ≈November 2007
  - Contract adjudication: ≈end of year
  - Payment: after installation June 2008

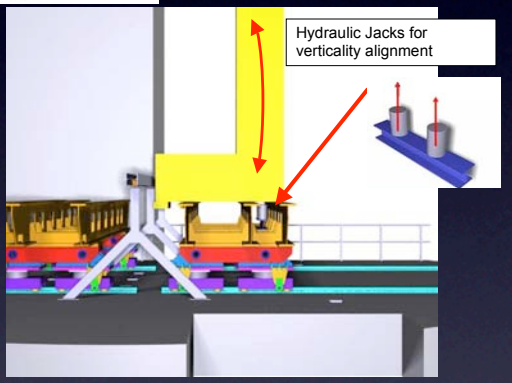
# Magnet integration (installation plan)



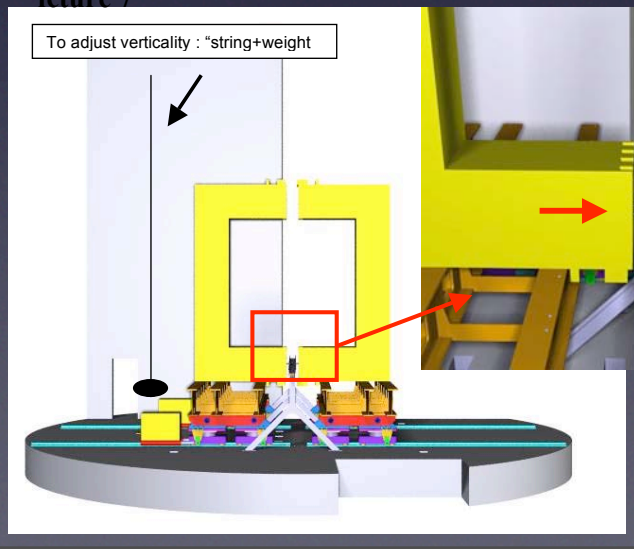


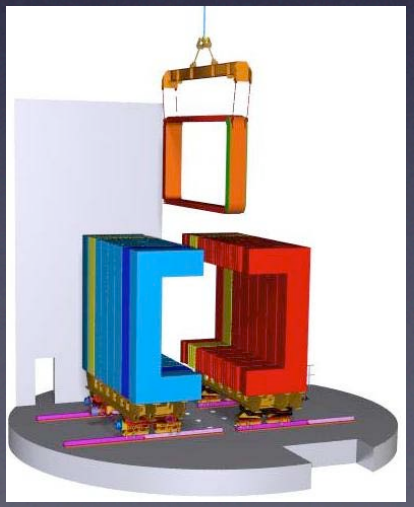



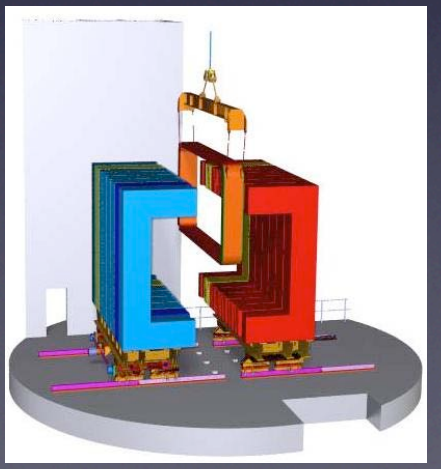




'icture 7

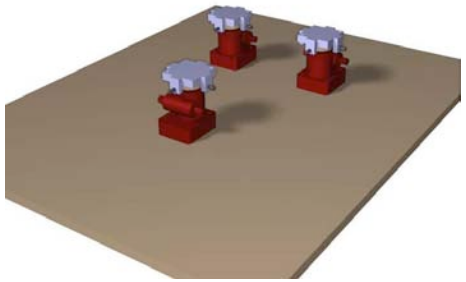


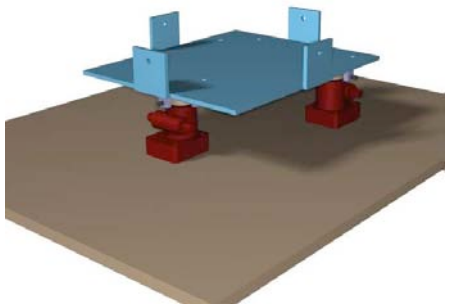


# Yoke reassembly

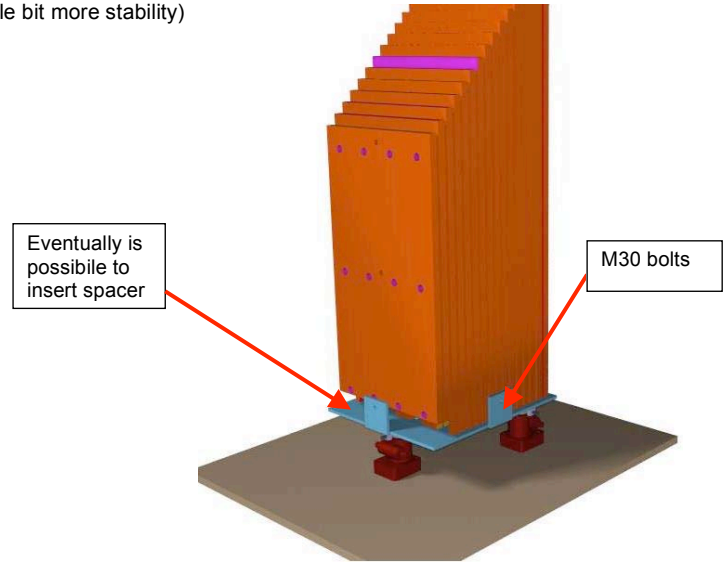
- Jacks are first fixed with bolts on floor.



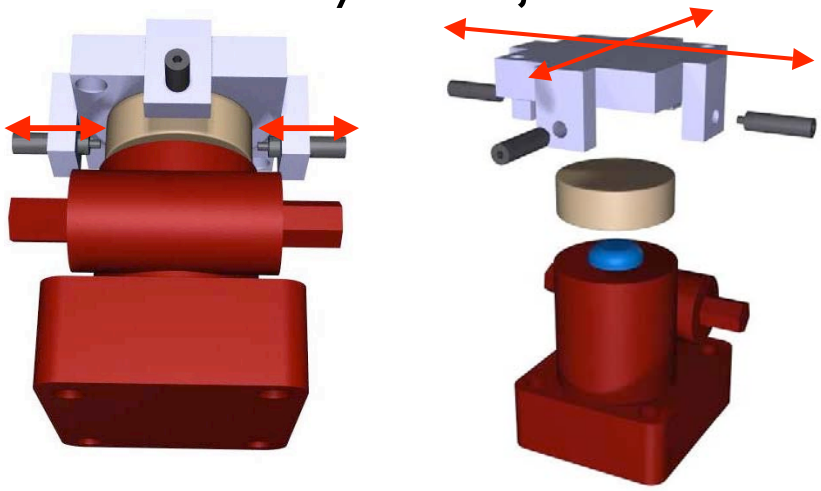
- Second, an iron plate is placed and fixed (with M16 Bolts) onto the Jacks to give more stability and to help the horizontally regulation.

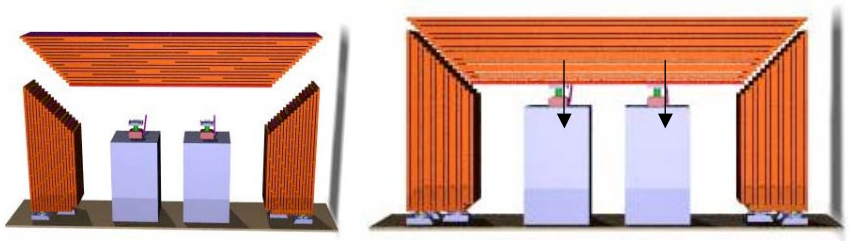


- Third , the yoke's leg is lowered down onto the iron plate and fixed with M30 Bolts (also this for a little bit more stability)




Hydraulic jacks





1 day/yoke

test reassembly @ CERN planned for October/November

# Conclusions

- The T2K experiment will be the first accelerator experiment to look for the the last mixing angle ($\theta_{23}$~45°, $\theta_{12}$~34°, test $\theta_{13}$ to 3°) and measure more precisely $\Delta m^2_{23}$.
  - Determine future direction of neutrino experiment
  - Lead to a possible test of CPV in leptons
  - Look for the unexpected with precision measurements of oscillation pattern / parameters
- Construction schedule is tight but on track for beam commissioning in 2009
- Swiss contributions visible and well-defined.
- Magnet project on track: shipment and installation foreseen for Spring 2008.

# The End