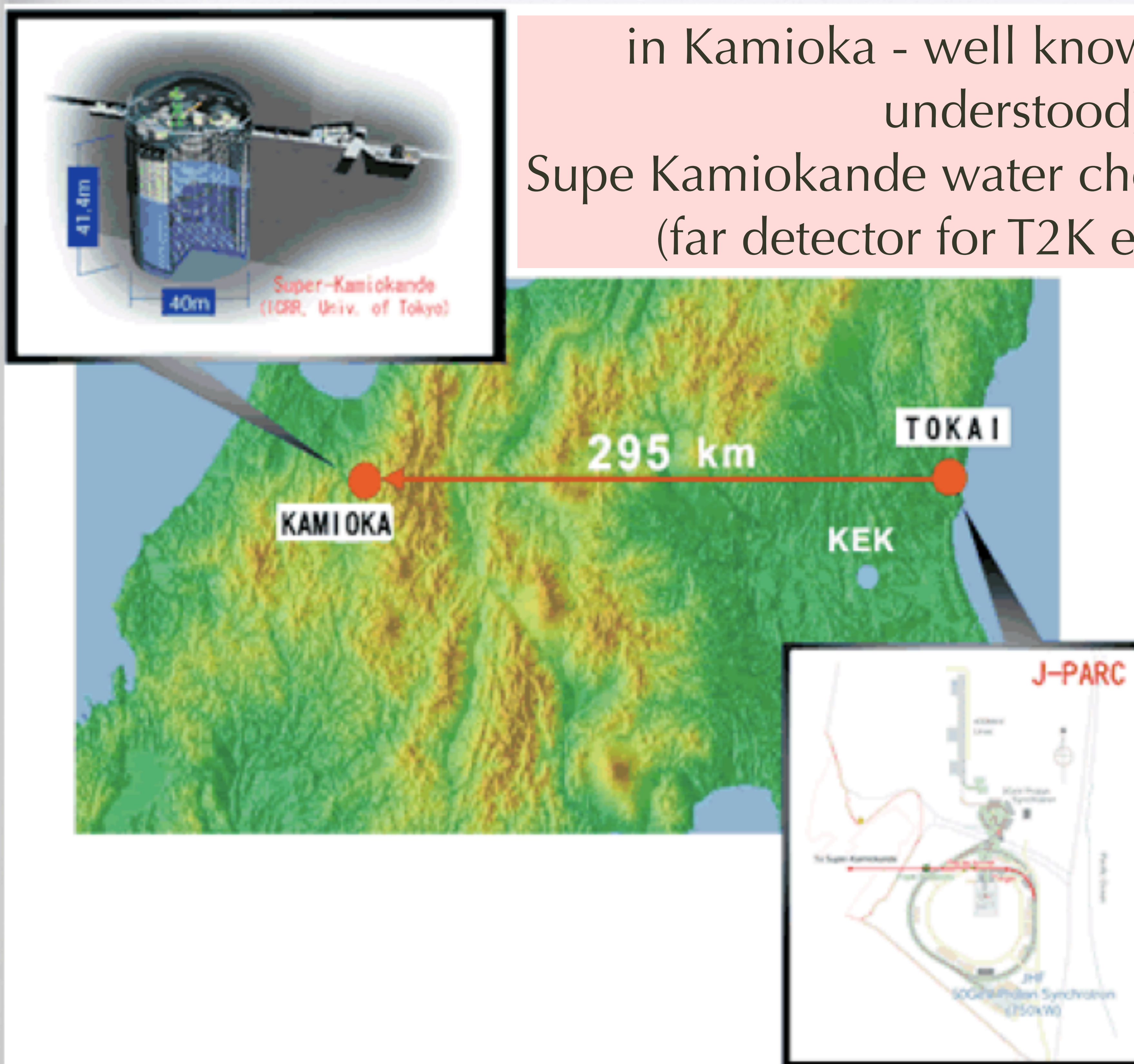
T2K experiment

Ewa Rondio
A.Sołtan Institute for Nuclear Studies

V Polish Workshop on Relativistic Heavy-Ion Collisions
SHIN(E)ing Physics

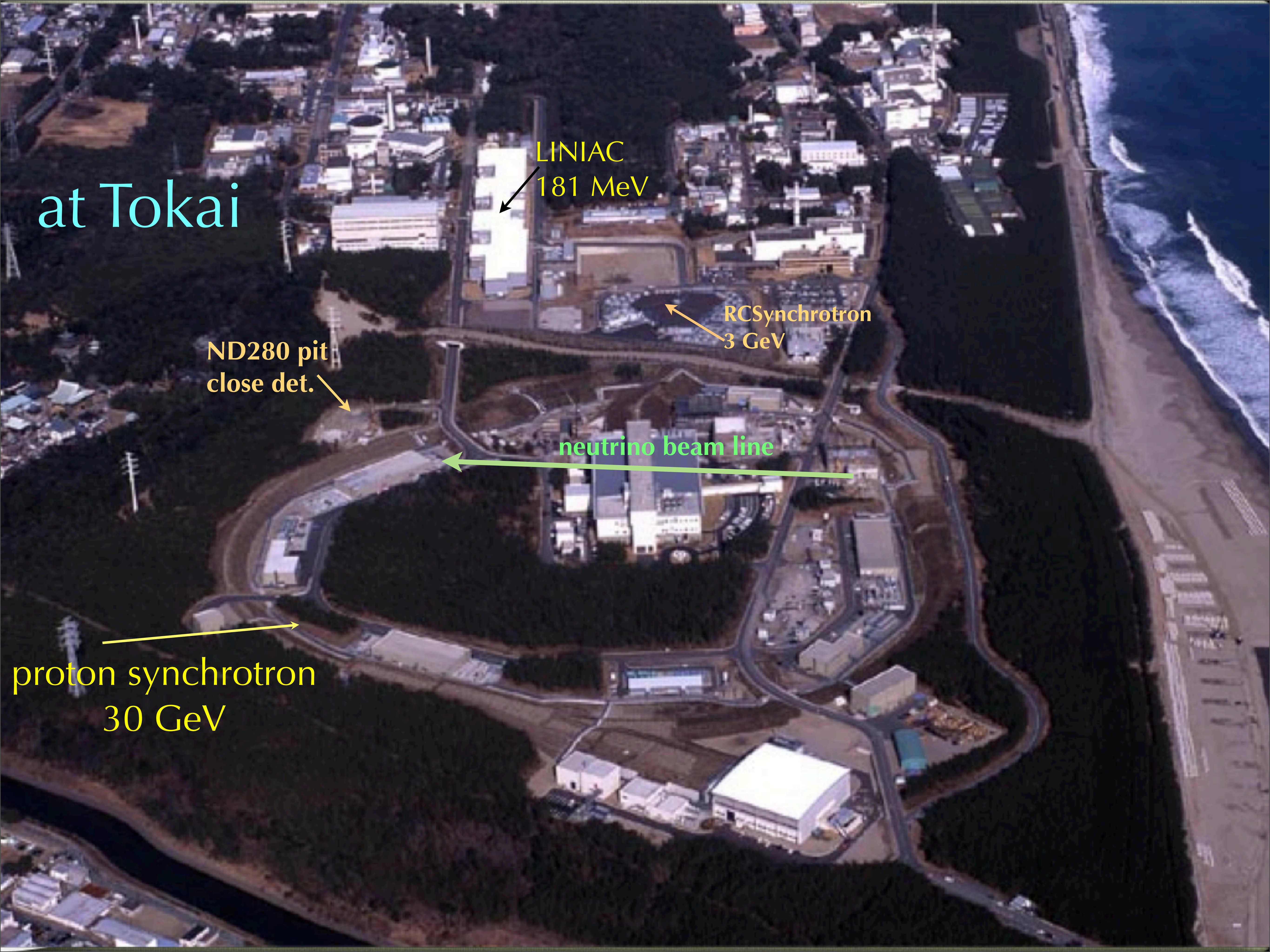
Kielce, December 6'th 2008

Tokai to Kamioka = T2K

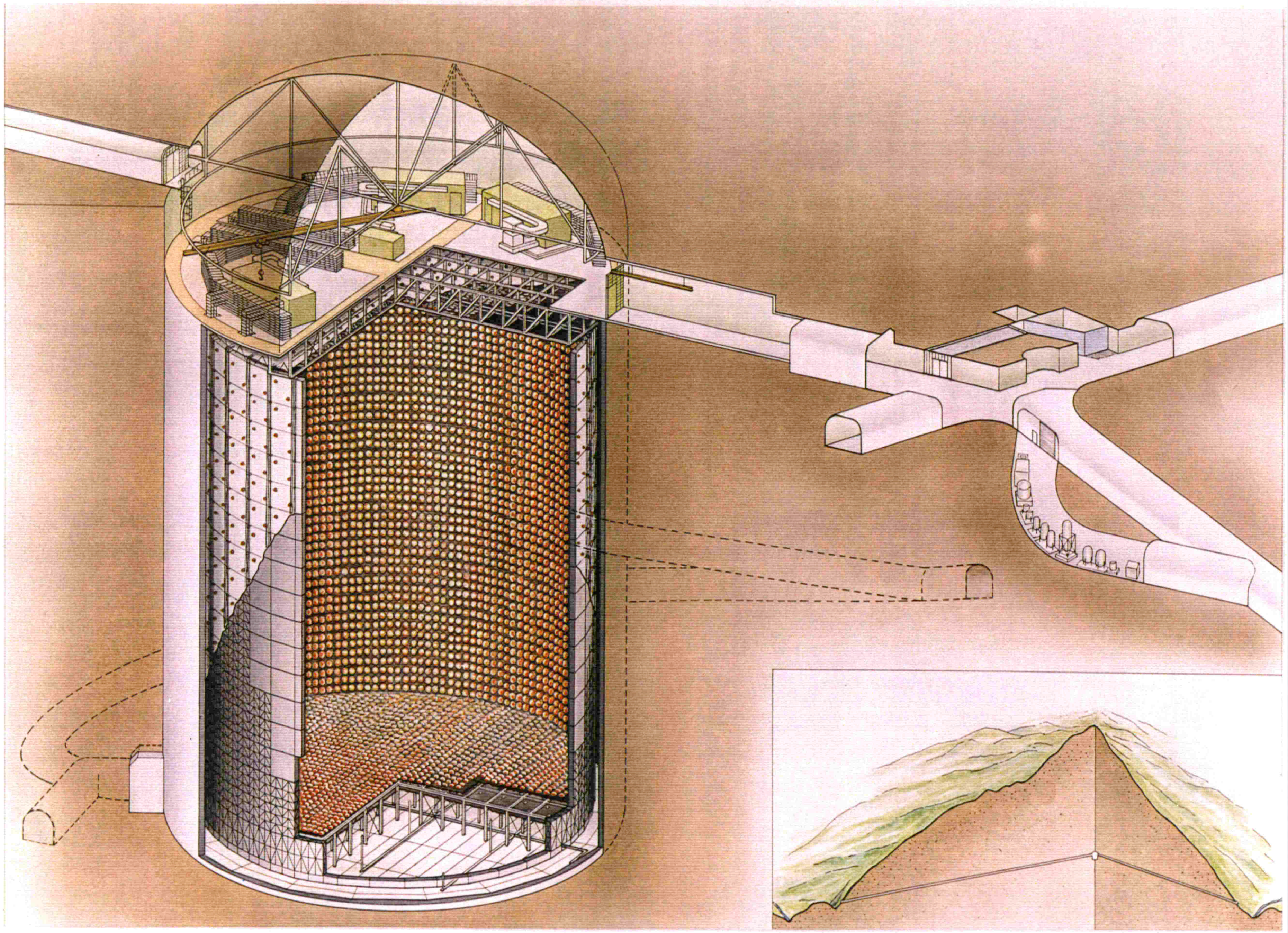


in Kamioka - well known (and well understood)
Supe Kamiokande water cherenkov detector
(far detector for T2K experiment)

at Tokai -
accelerator
for protons, high intensity
energy - 30 GeV
neutrino beam
beam monitor(s)
close detector (ND280)


at Tokai
LINIAC
181 MeV
RCSynchrotron
3 GeV
ND280 pit
close det.
neutrino beam line
proton synchrotron
30 GeV

Super-Kamiokande

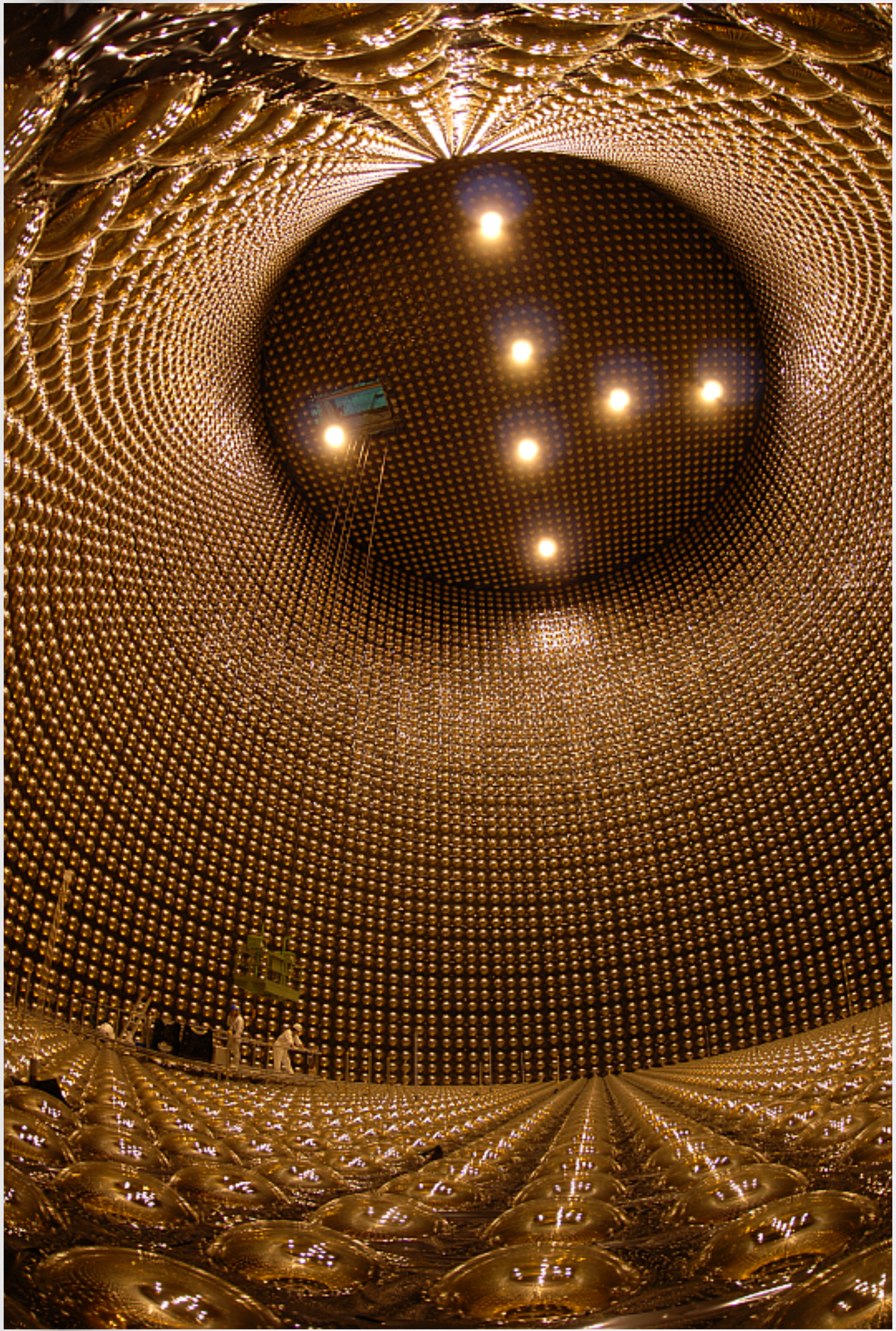


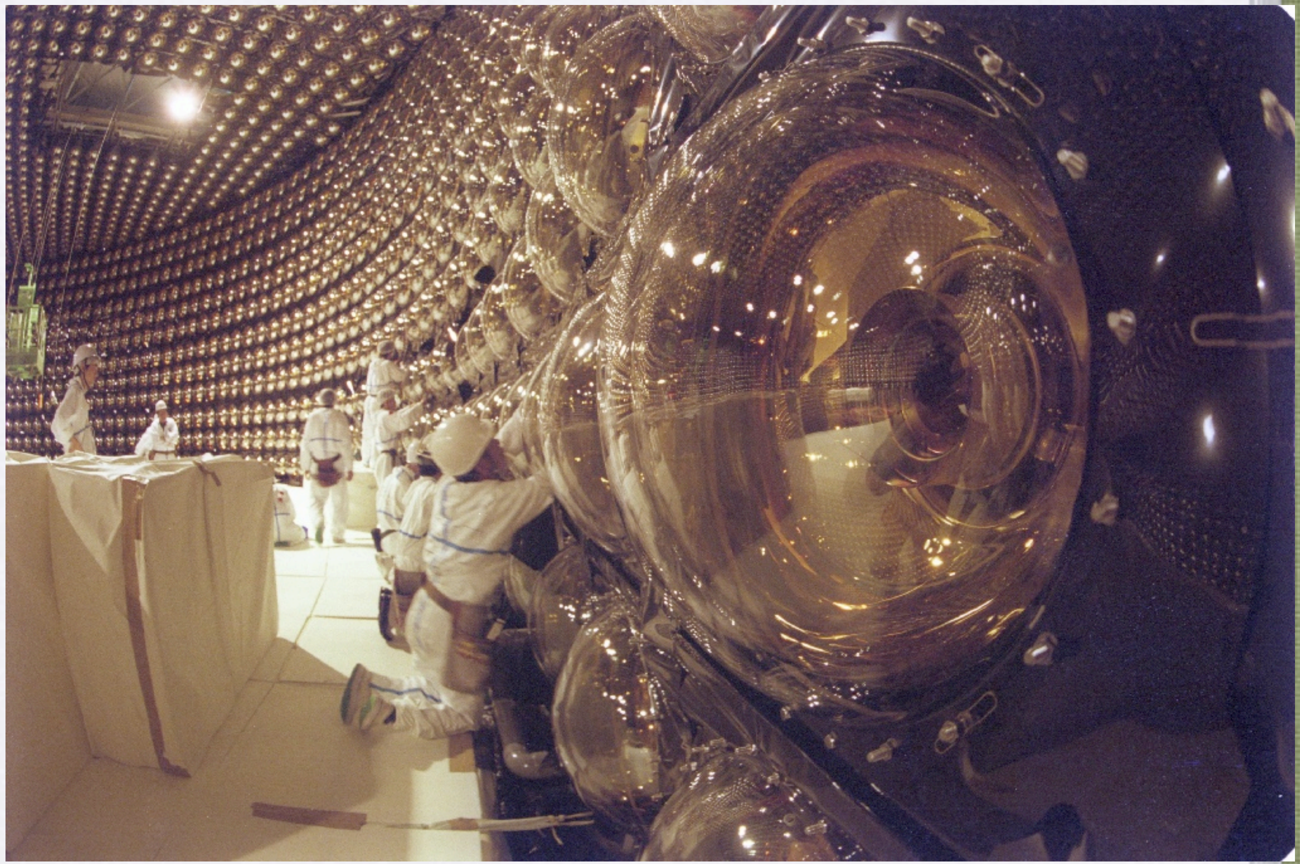
Water Cerenkov detector in Kamioka, Japan

- 50kton water, 22.5kton fiducial volume
- 12k inner PMTs /2k outer PMTs

detect light; possible reconstruction of energy and direction of neutrinos

- SK investigates atmopsheric/cosmic, solar & accelerator ν
- detect SN1987 ν's
- neutrino oscillation discovery (1998)





goals of the T2K experiment

$\nu_\mu \Leftrightarrow \nu_\tau$

Low energy, disappearence experiment,
compare expected with observed # of events

- - measurements of the muon neutrino disaperance -θ_{23} , Δm^2_{23}
  - precision on mixing angle and mass difference for "atmospheric" sector

$\nu_\mu \Leftrightarrow \nu_e$

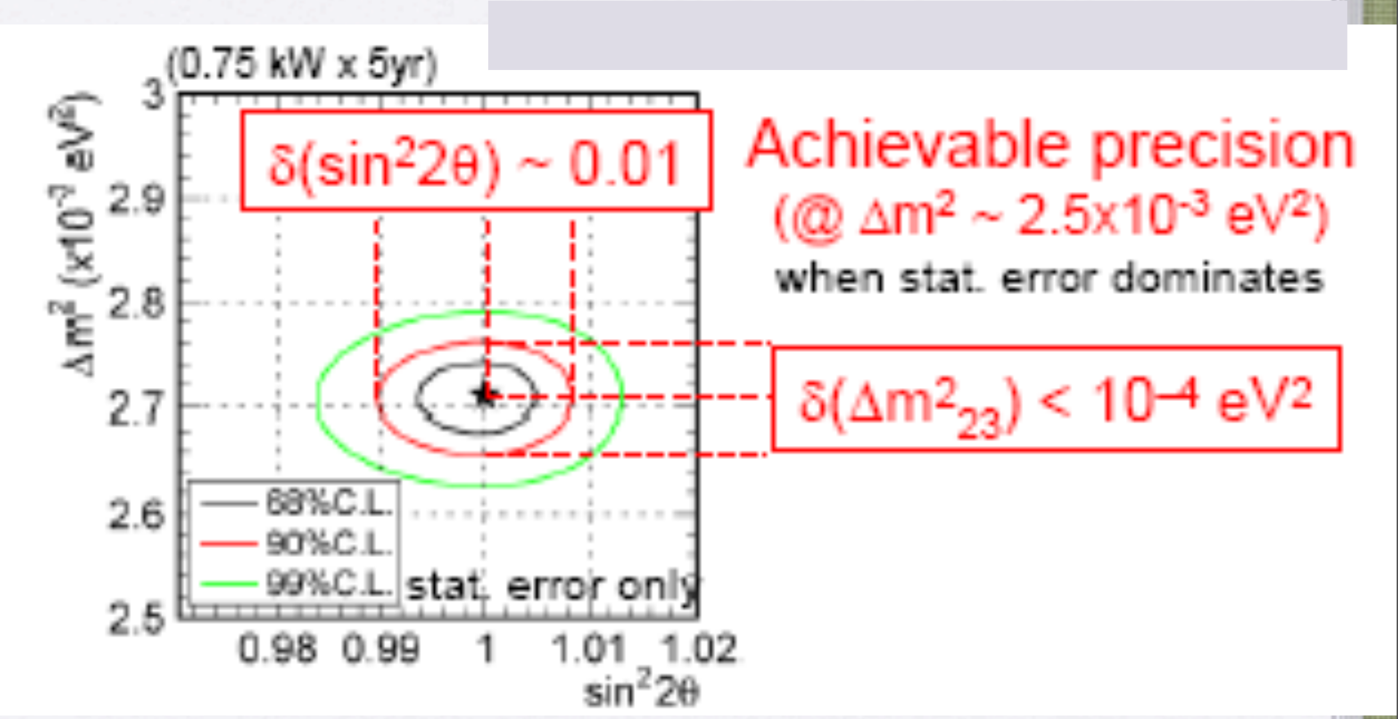
Search for electrons, background from decays of π^0 mezons
Interactions of ν_e existing in the beam

- main goal - measurement or better limit of the sub-dominant mixing angle θ_{13}(presently only limit θ_{13}<10°)

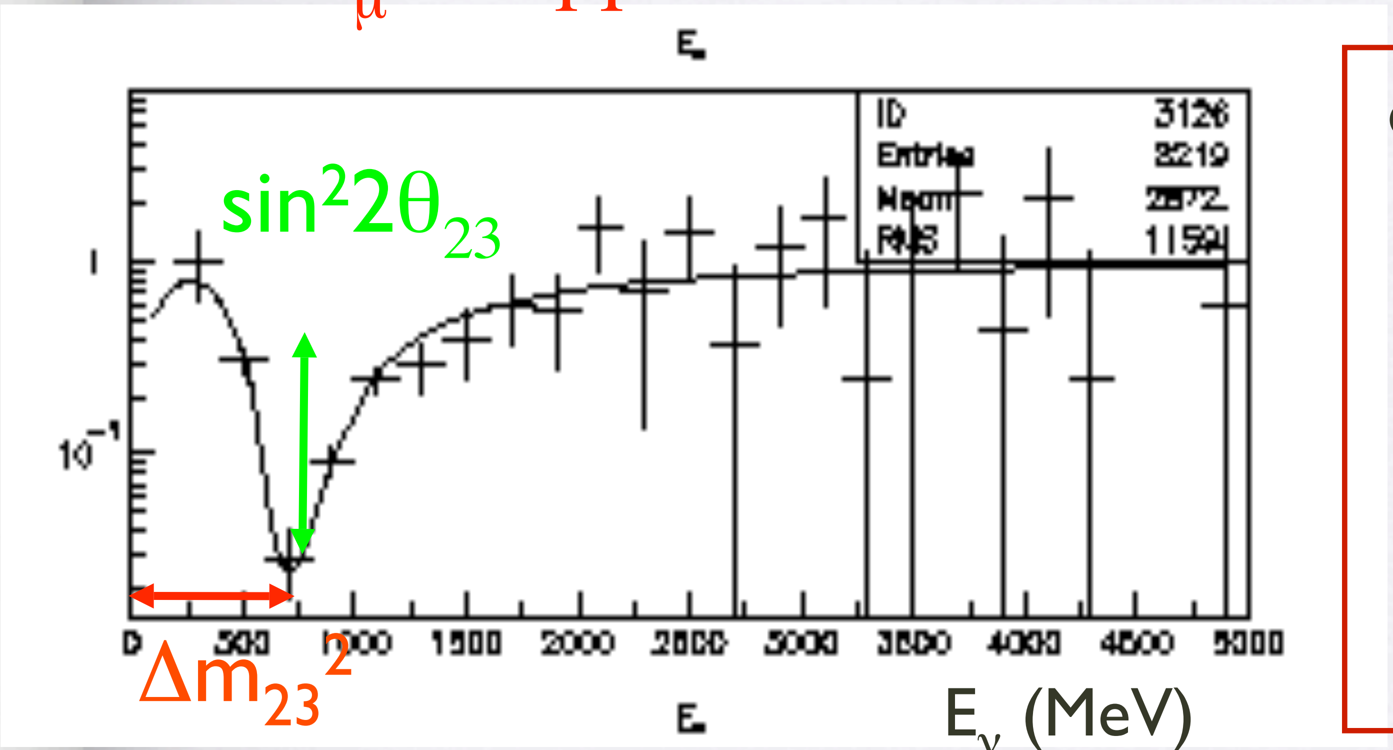
- later phase : **CP violation** in neutrino sector

early T2K measurements: $\sin^2 2\theta_{23}$, Δm^2_{23}

- Phase 1:
  - 5 years X 0.75 MW beam
  - 5×10^{21} pot
  - Measurement of mixing angles

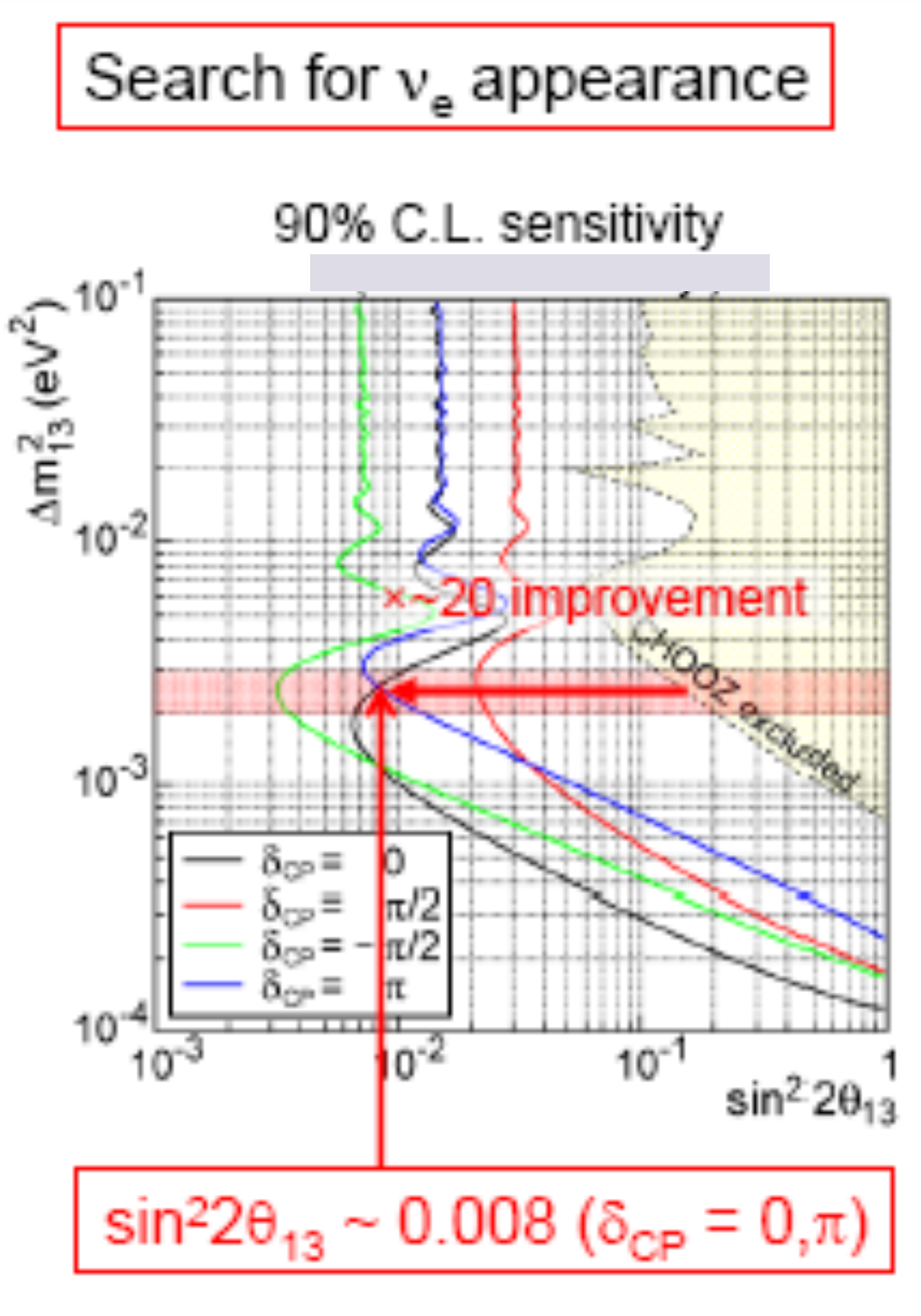


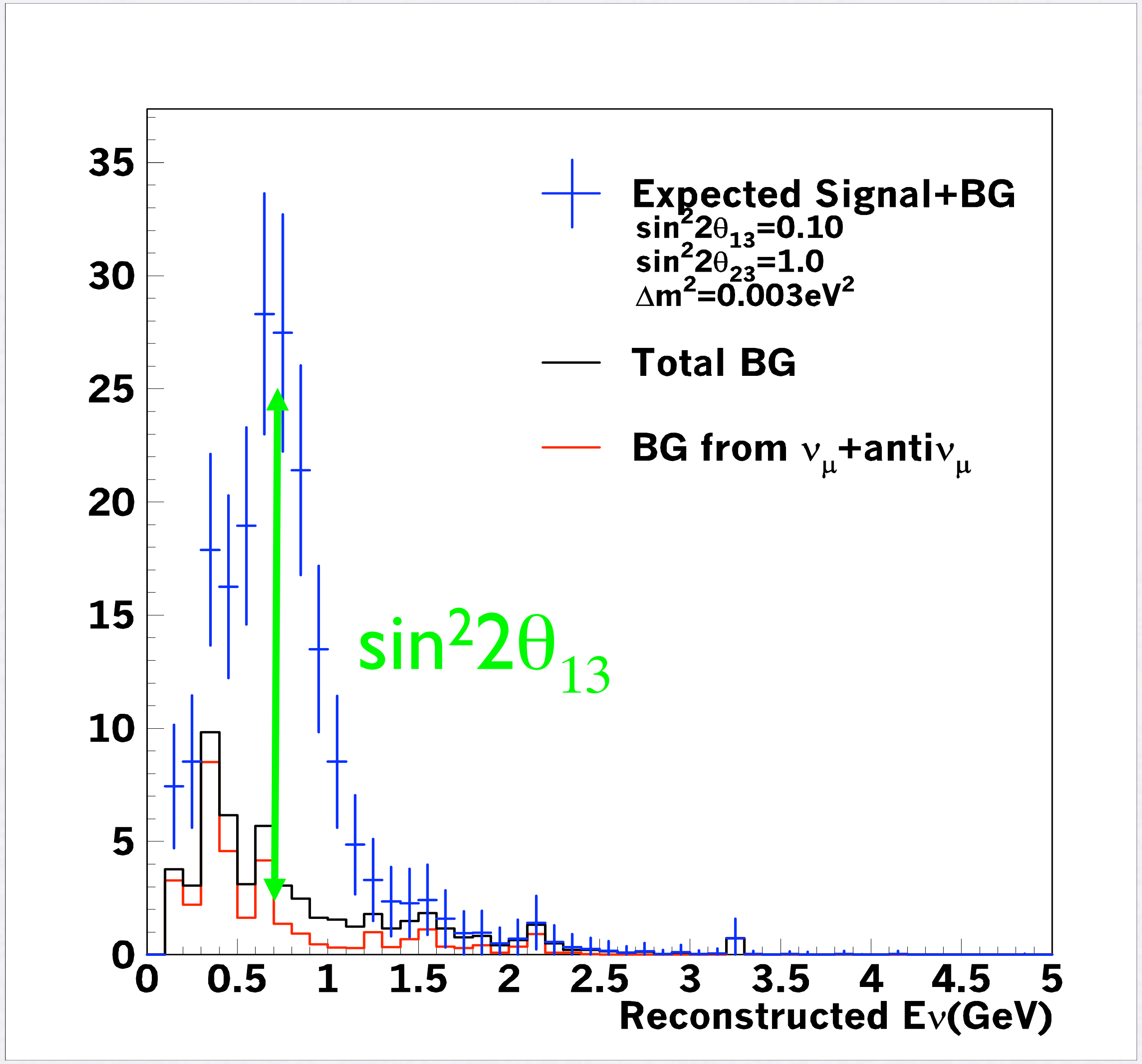
ν_μ disappearance



- Use CC Quasi Elastic Events
  - Can reconstruct Neutrino Energy.

Main T2K goal : $\sin^2 2\theta_{13}$



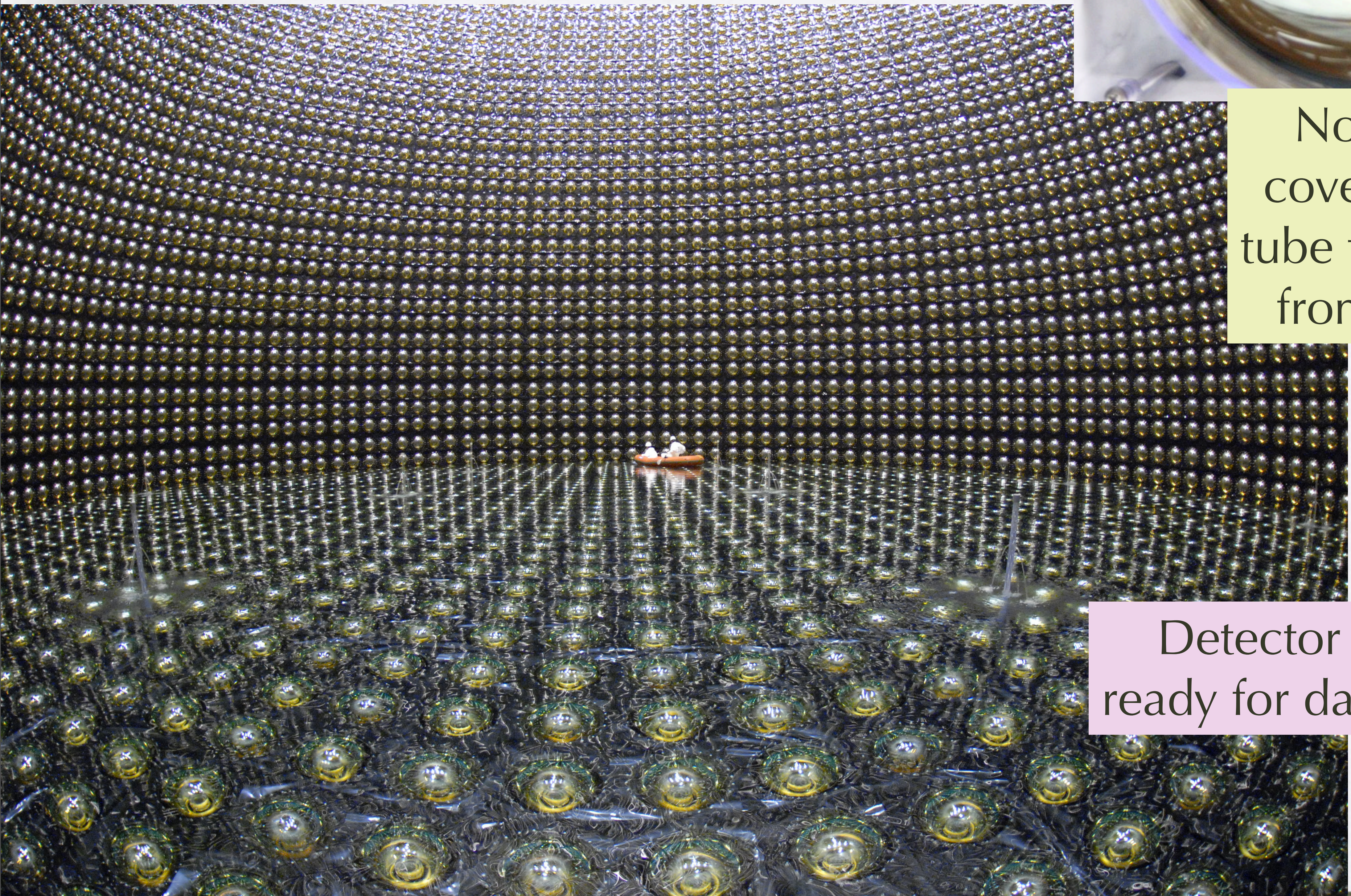


Main Backgrounds:

Beam ν_e contamination

NC π^0 events

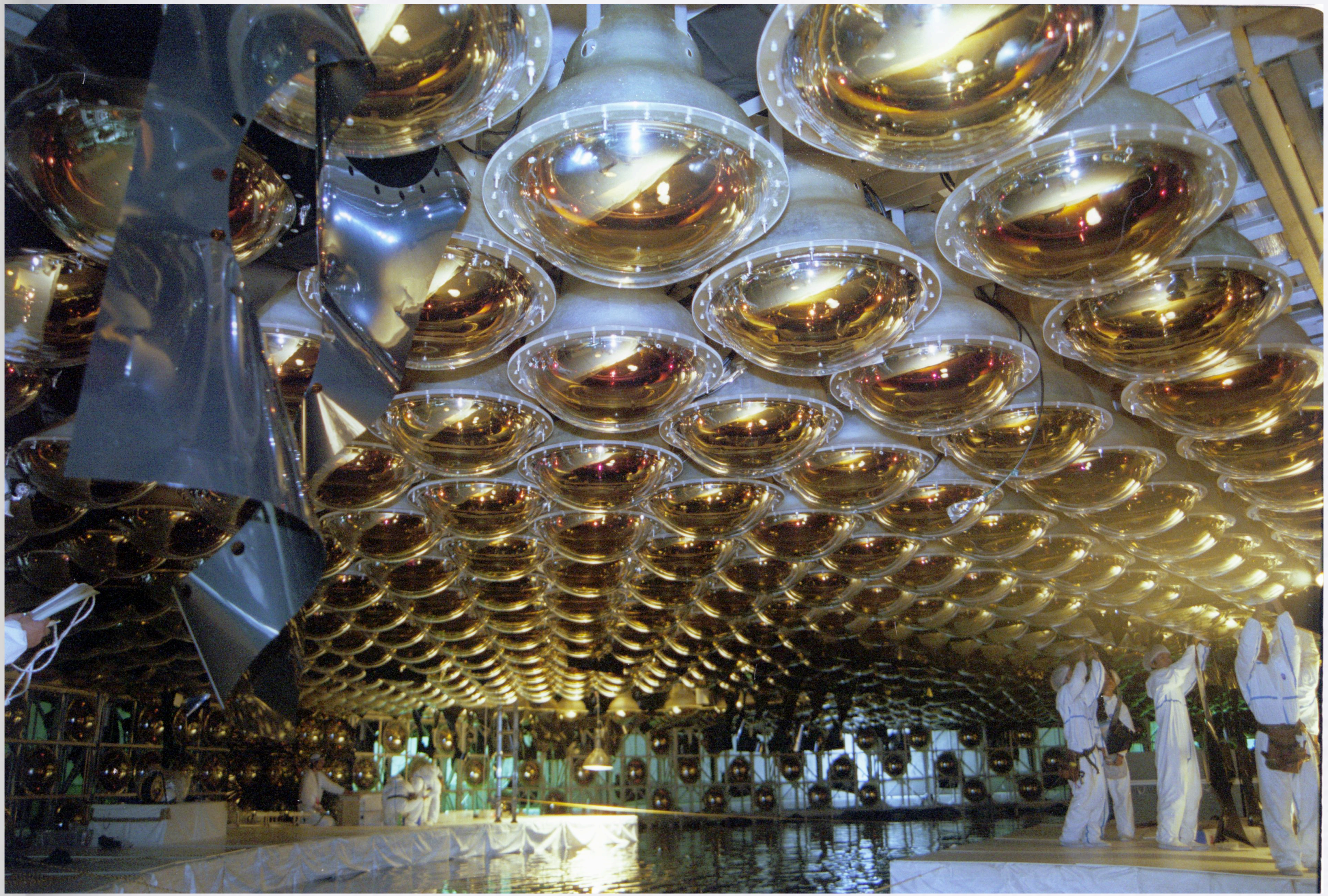
This is how it looked when filling with water started after repair (# of PMT's as before the

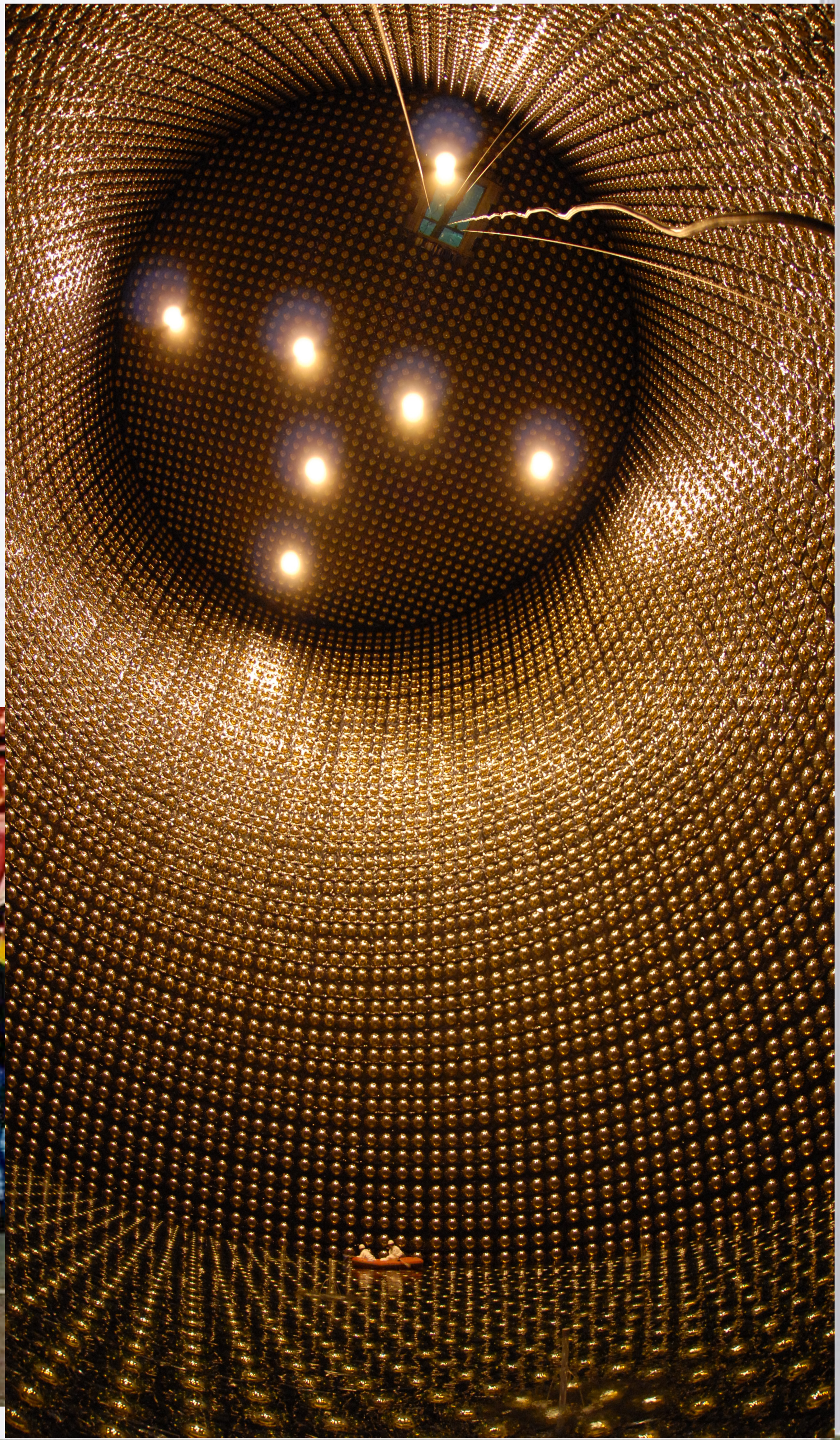


Now PMT's are covered by plastic tube to protect them from shock wave

Detector is working ready for data from Tokai

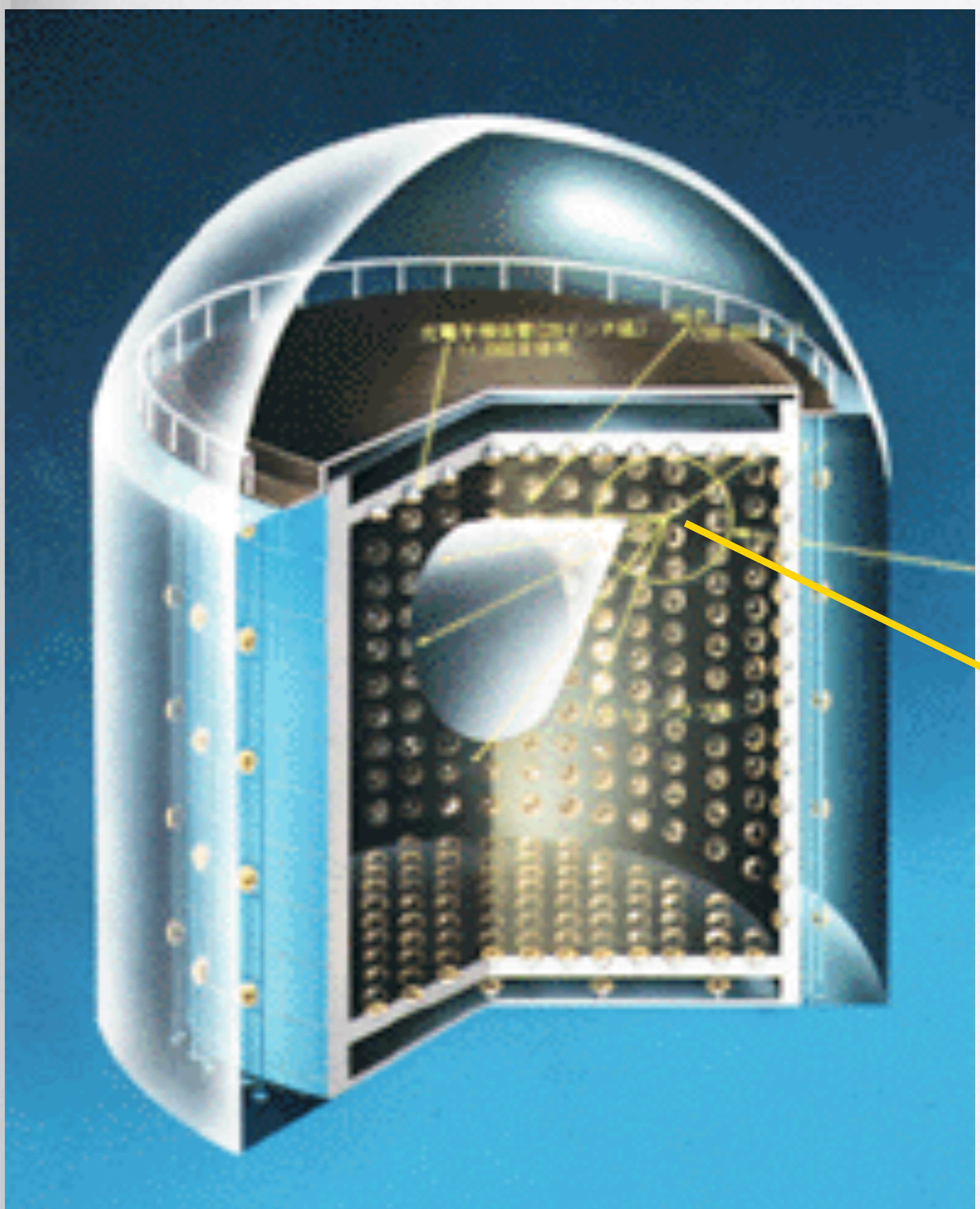
SK is very photogenic





Water Cerenkov detector principle

- Charged particles propagating with v > c in water emit e-m radiation

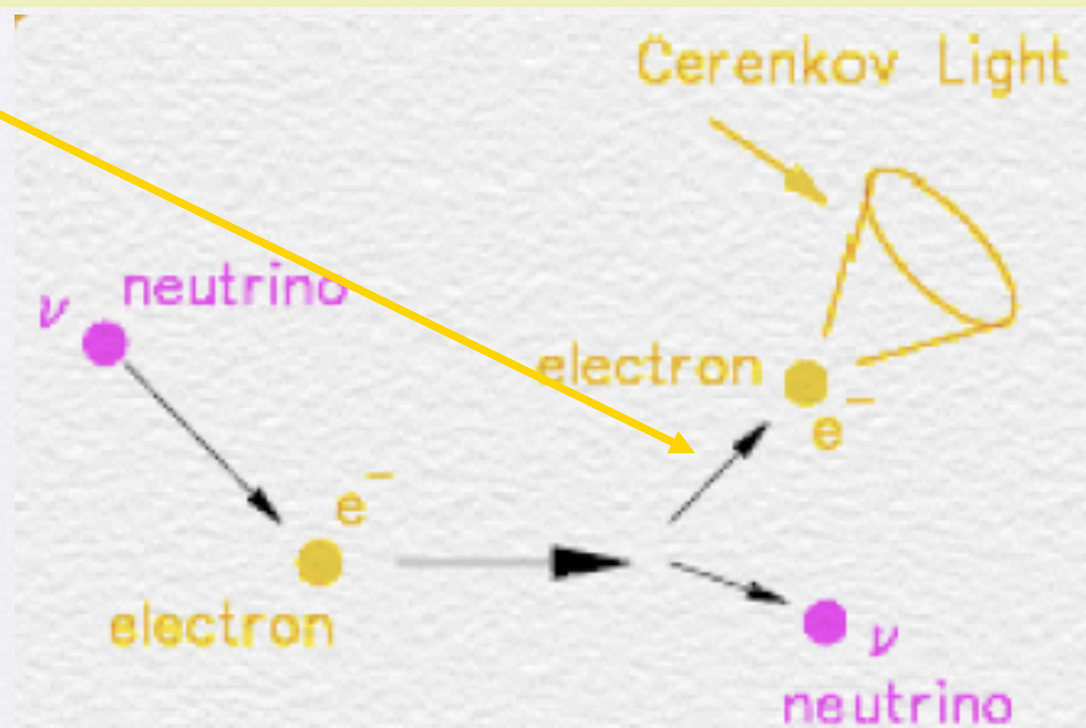


How to observe neutrino?

$$\nu_x + N \rightarrow e/\mu/\tau + N' + \ldots$$

$$\nu_x + N \rightarrow \nu_x + N' + \ldots$$

$$\nu_e + e^{in-atom} \rightarrow \nu_e + e^{fast}$$

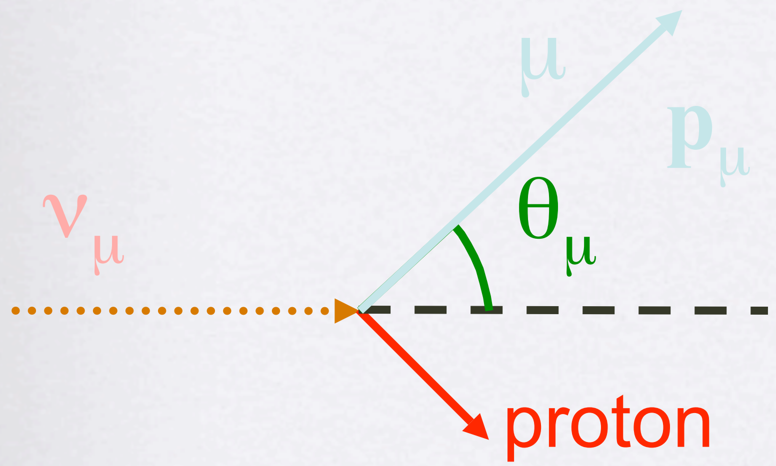


Reconstruction of neutrino energy

Use only single-ring μ-like fully contained events

Assuming **QE** interactions:

(~50% of single ring events are **QE**)

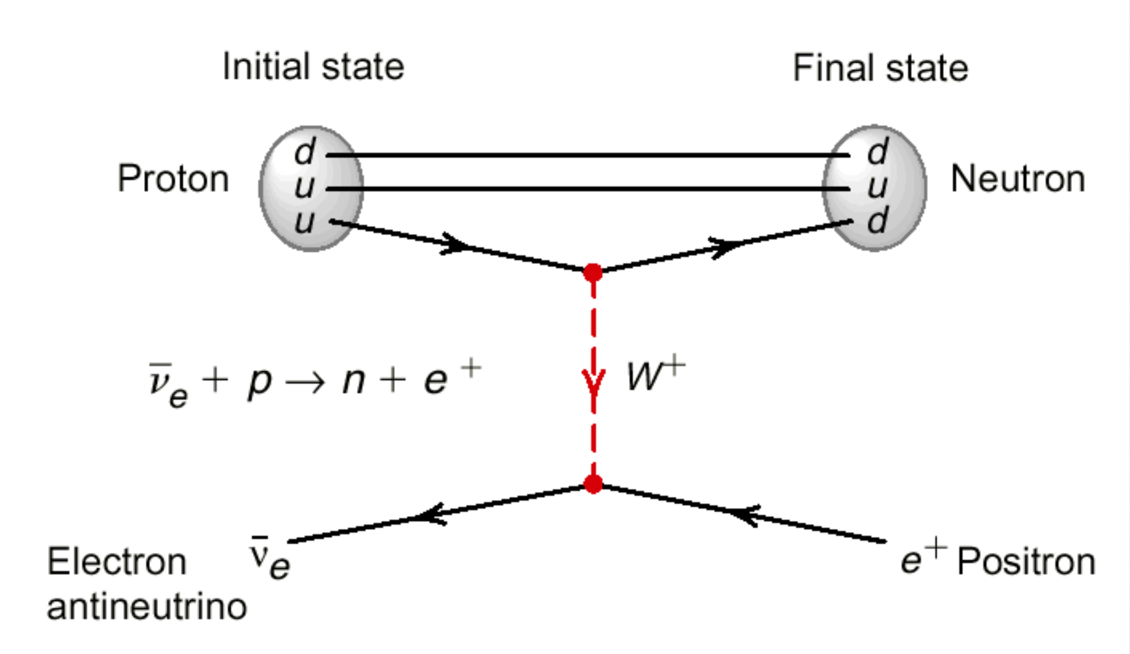


$$E_\nu^{rec} = \frac{m_n E_\mu - m_\mu^2 / 2}{m_n - E_\mu + P_\mu \cos\theta_\mu}$$

$\mathbf{E}_\mu$: muon energy

$\mathbf{p}_\mu$: muon momentum

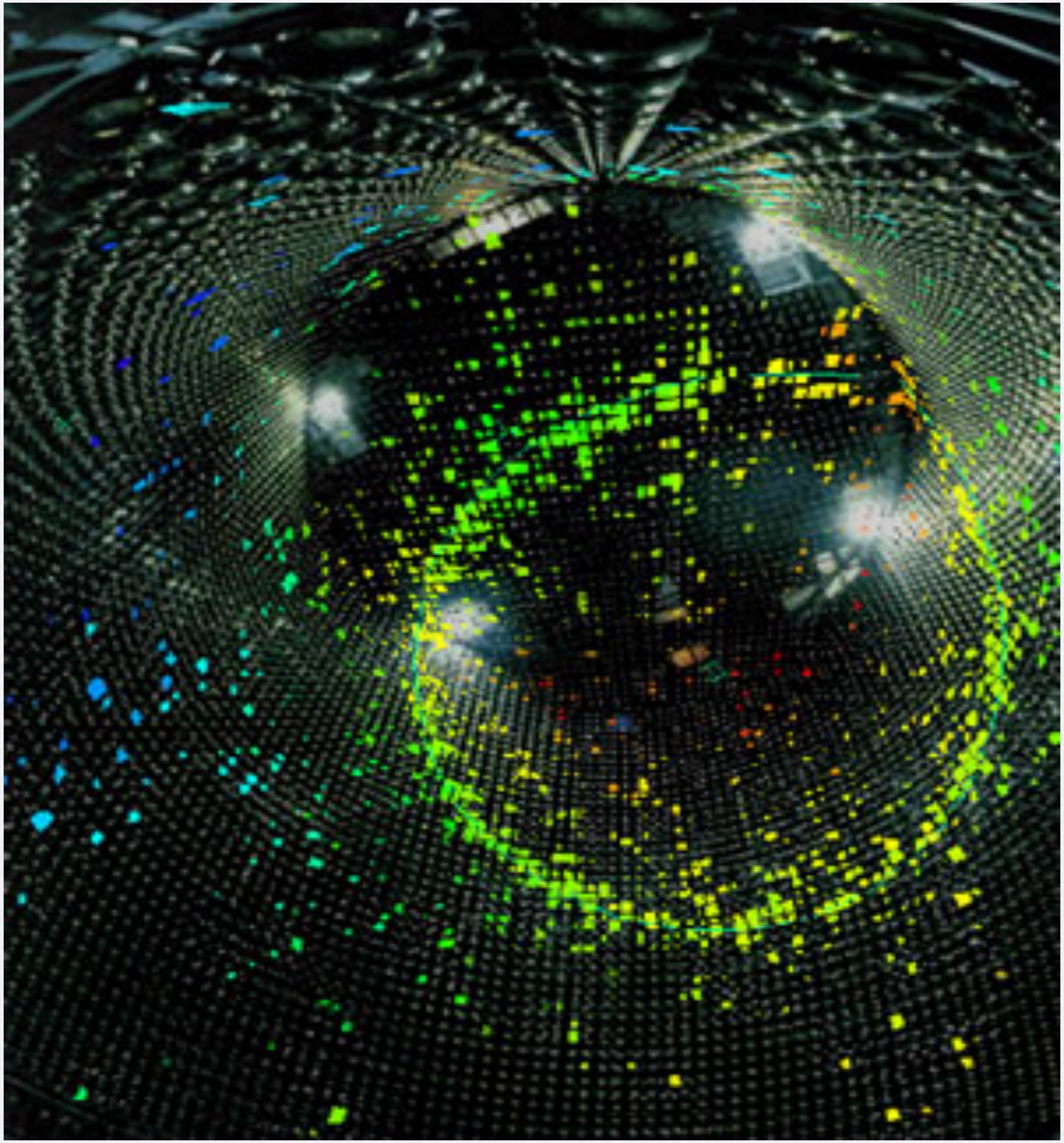
θ_μ : muon angle



Super-Kamiokande

Cerenkov ring categories:

- e-like (e, π^0)
- μ-like (μ, π+, π-, kaons…)



from the signal size we have information about energy of the particle deposited in the detector

from time of signal in each PMT vertex position can be reconstructed

open "ring" - particle stopped inside the detector

ring filled completely - particle left the detector (reach wall in the ring center)

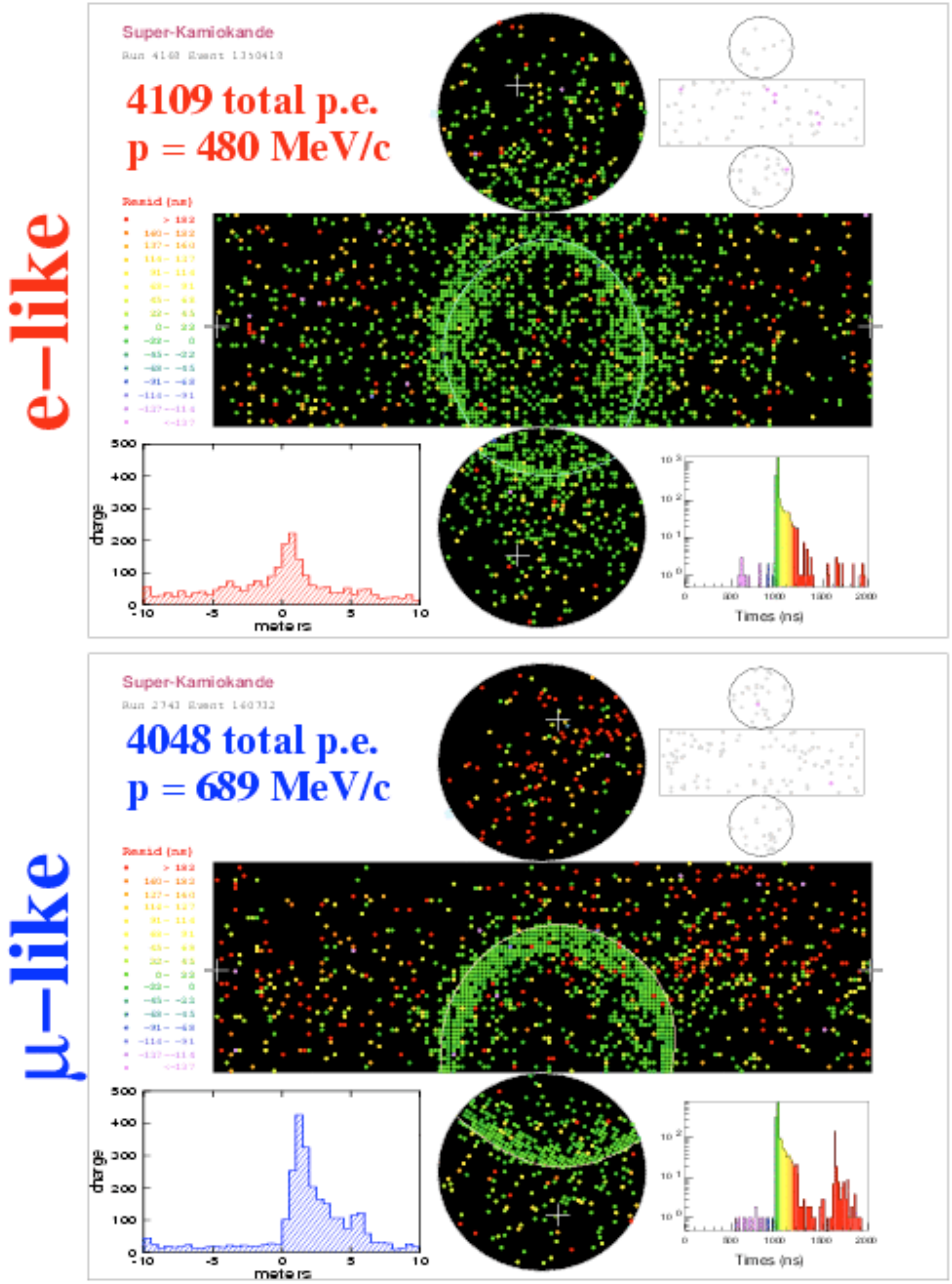
source: Science@berkeley lab, 30 January 2006

Particle identification

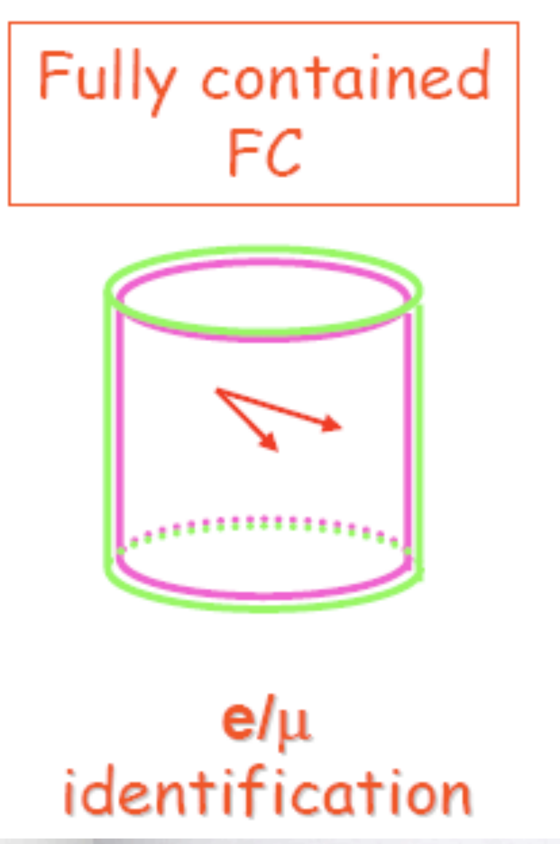
electrons, gammas:

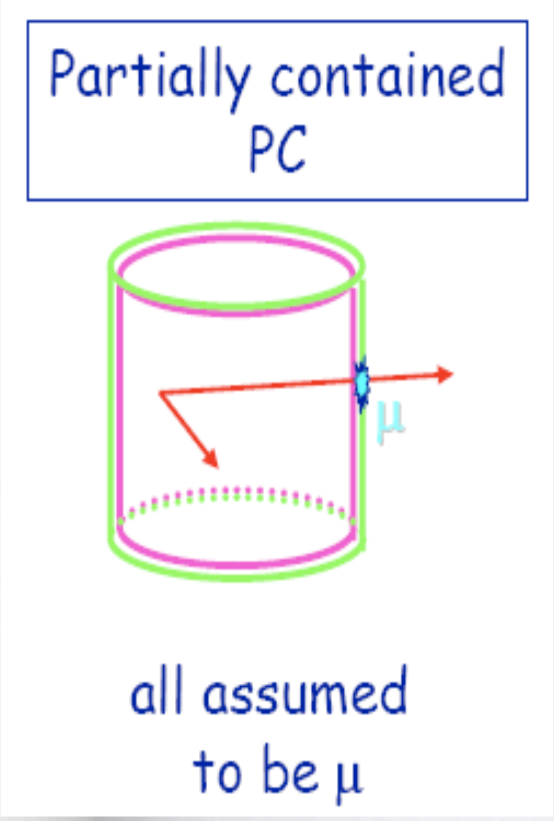
muons, pions, protons:

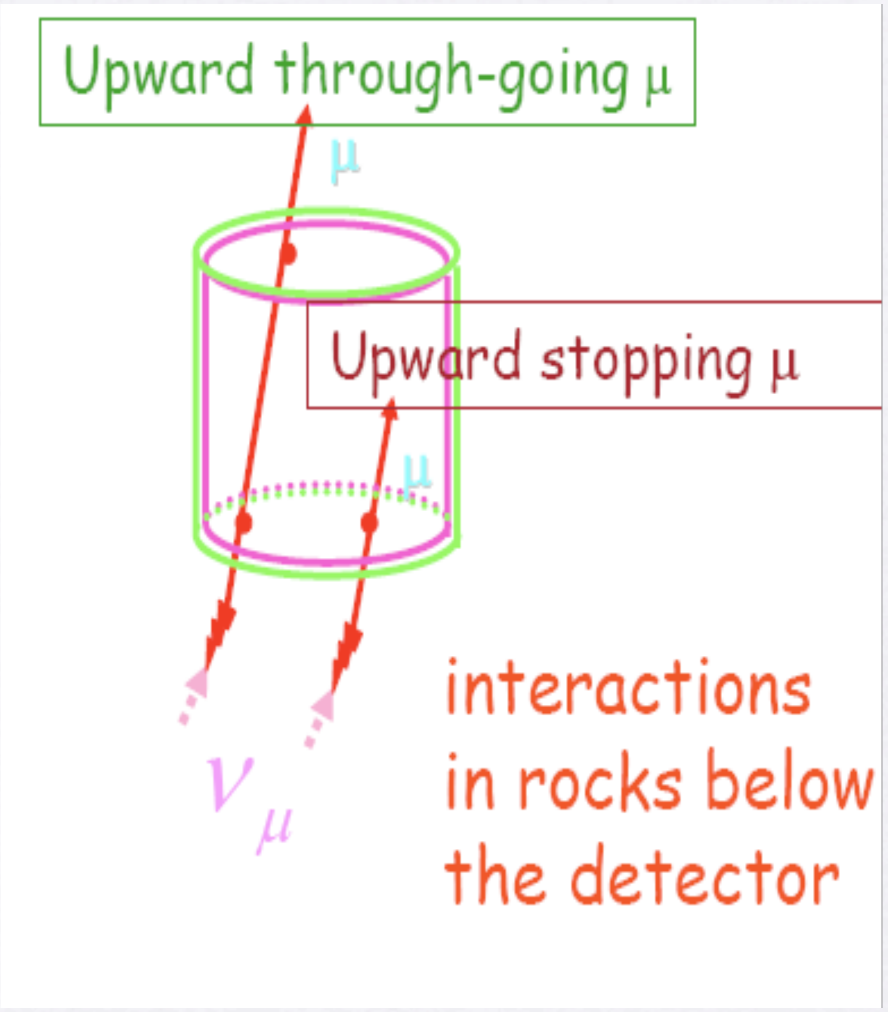
Used in atmospheric ν detection

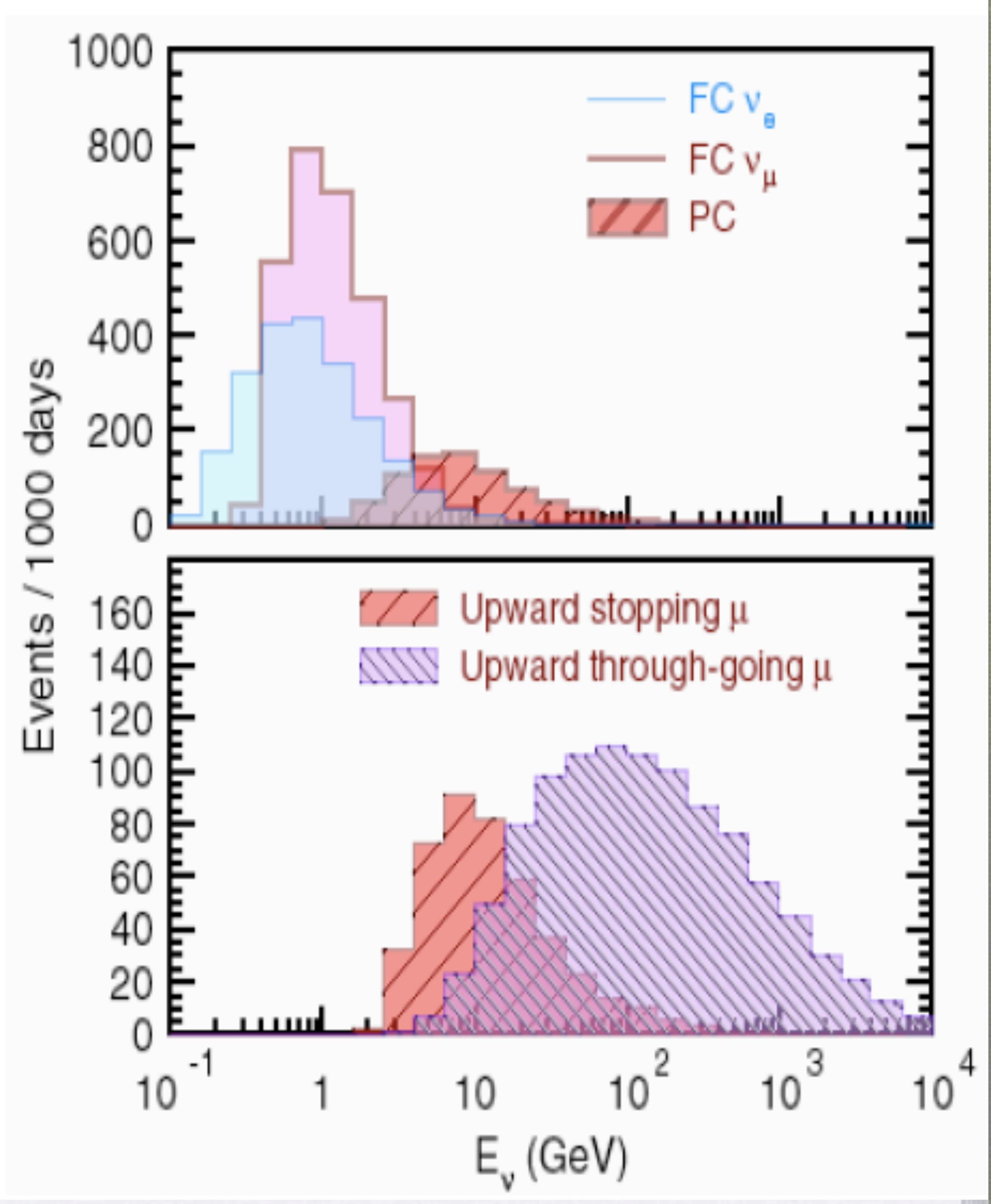


Neutrino events in Super-Kamiokande



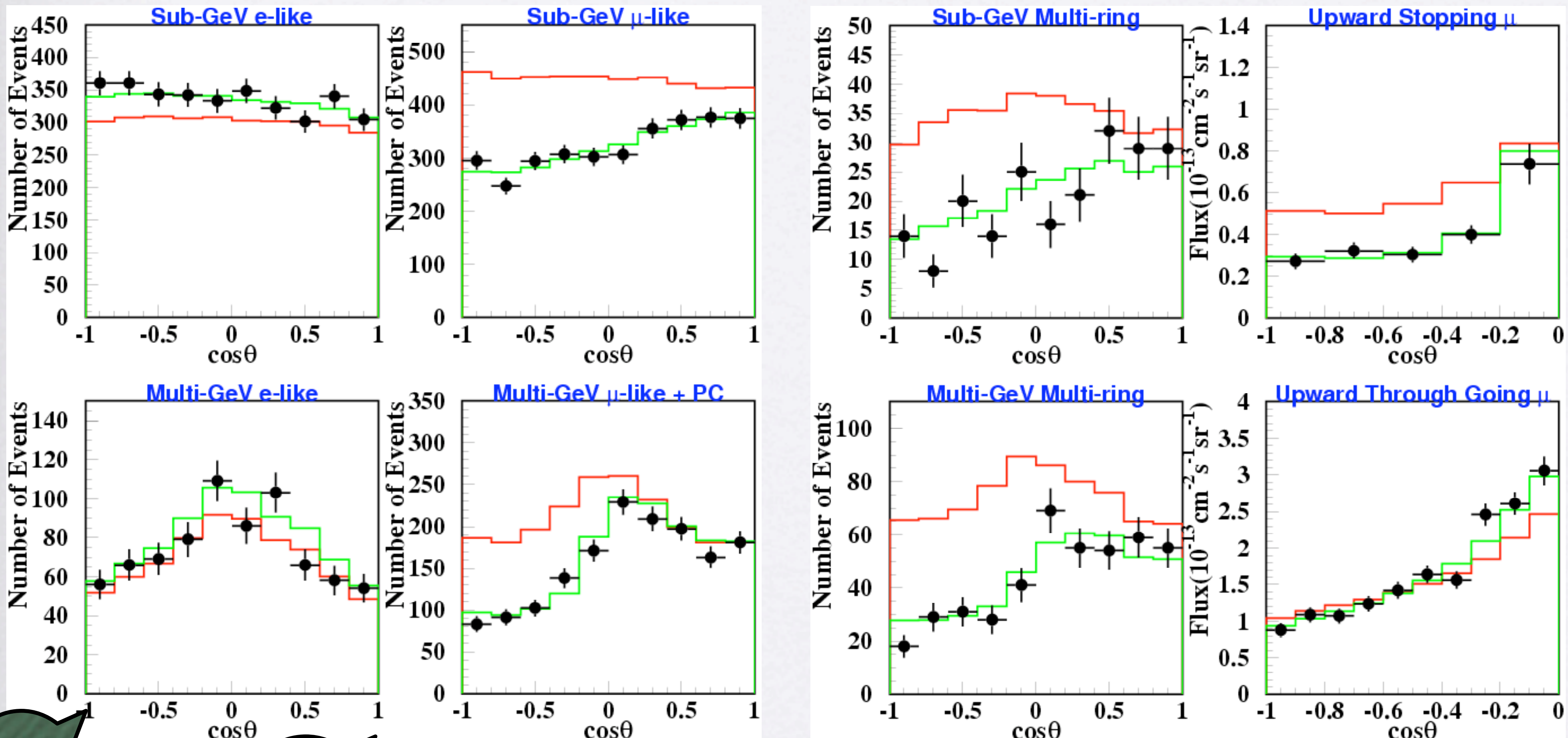






Monte Carlo

results **on neutrino oscillations** from Super Kamiokande

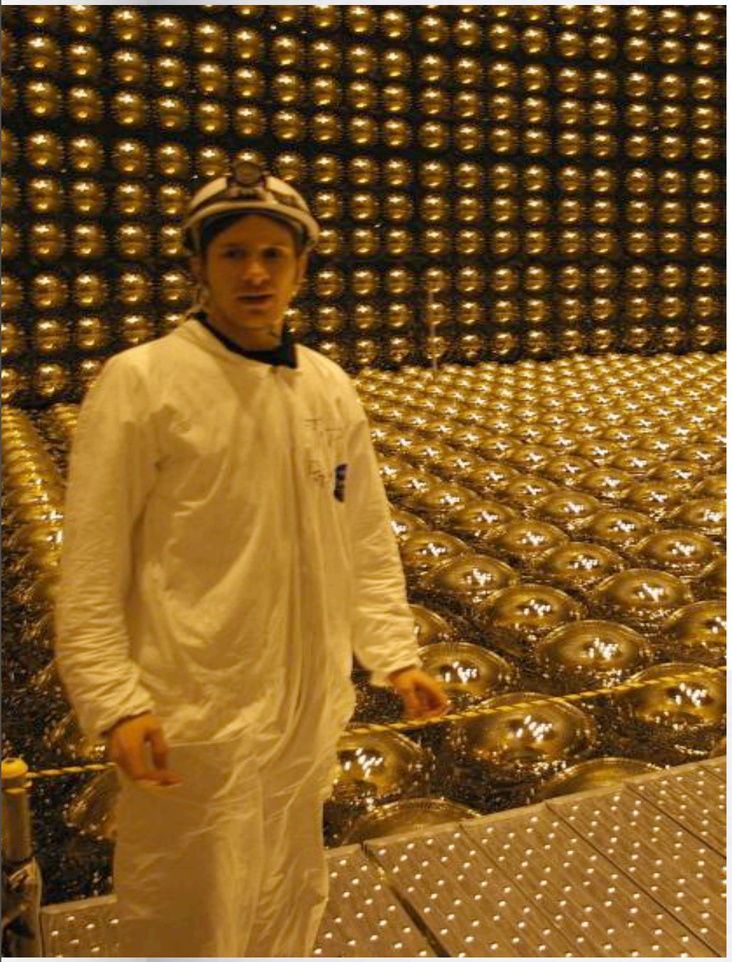


up

down

zenith angle distributions

this is converted to oscil.param.



SK is ready for taking data from neutrino beam

--> full coverage by PM's

--> improved, new electronics

- to fulfill the goals one needs measurements of events in the far detector (SK) and **predictions** for expected number of events without oscillation effects

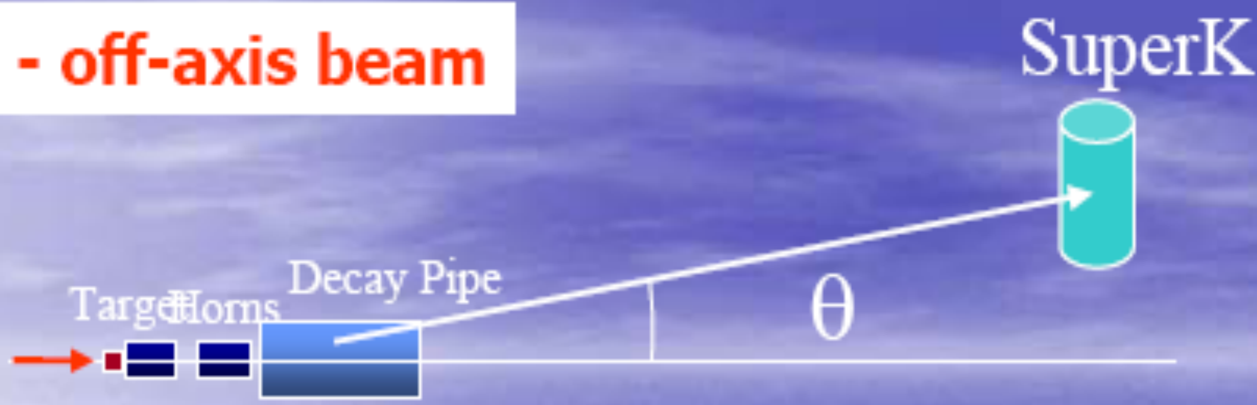
- for predictions we need:

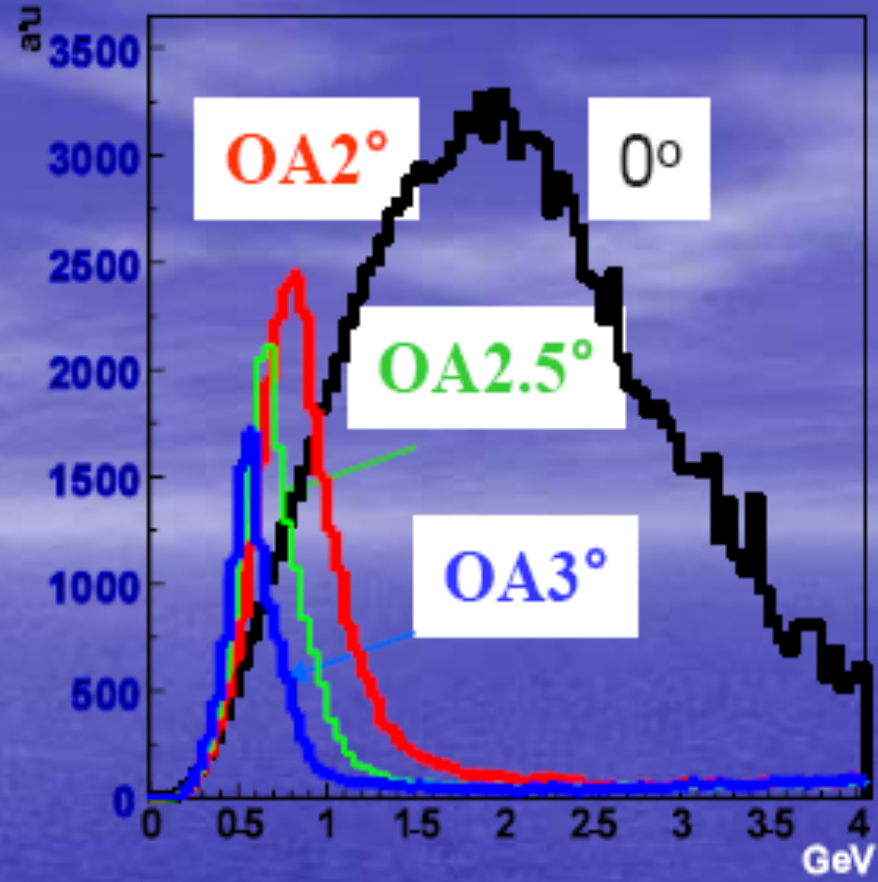
precise knowledge of neutrino beam (NA61 data --> see next talk)

good knowledge on neutrino interaction cross sections (for all channels contributing to signal (QE) and background

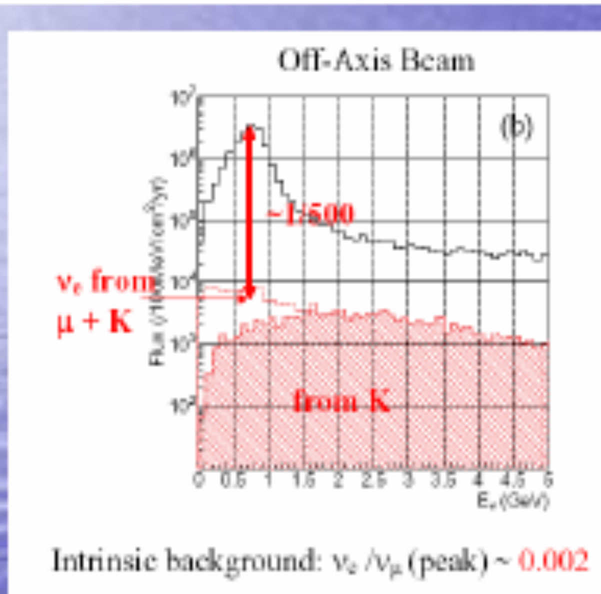
T2K principles

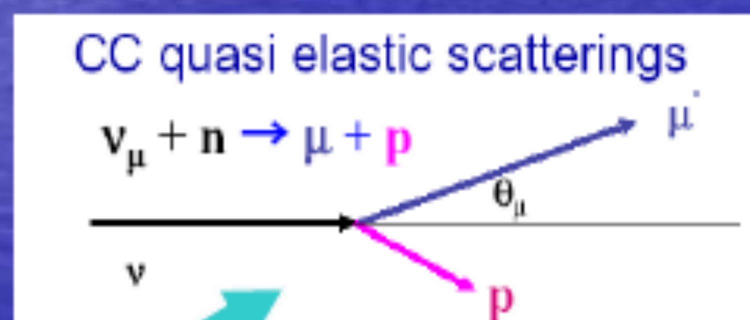
- off-axis beam





- small contamination of ν_e

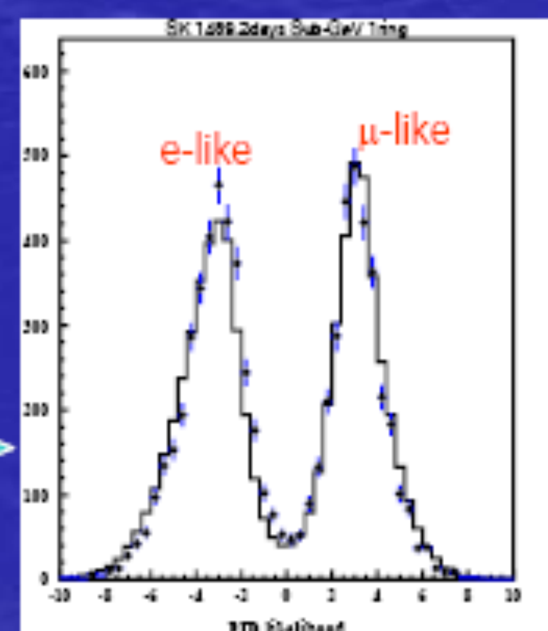




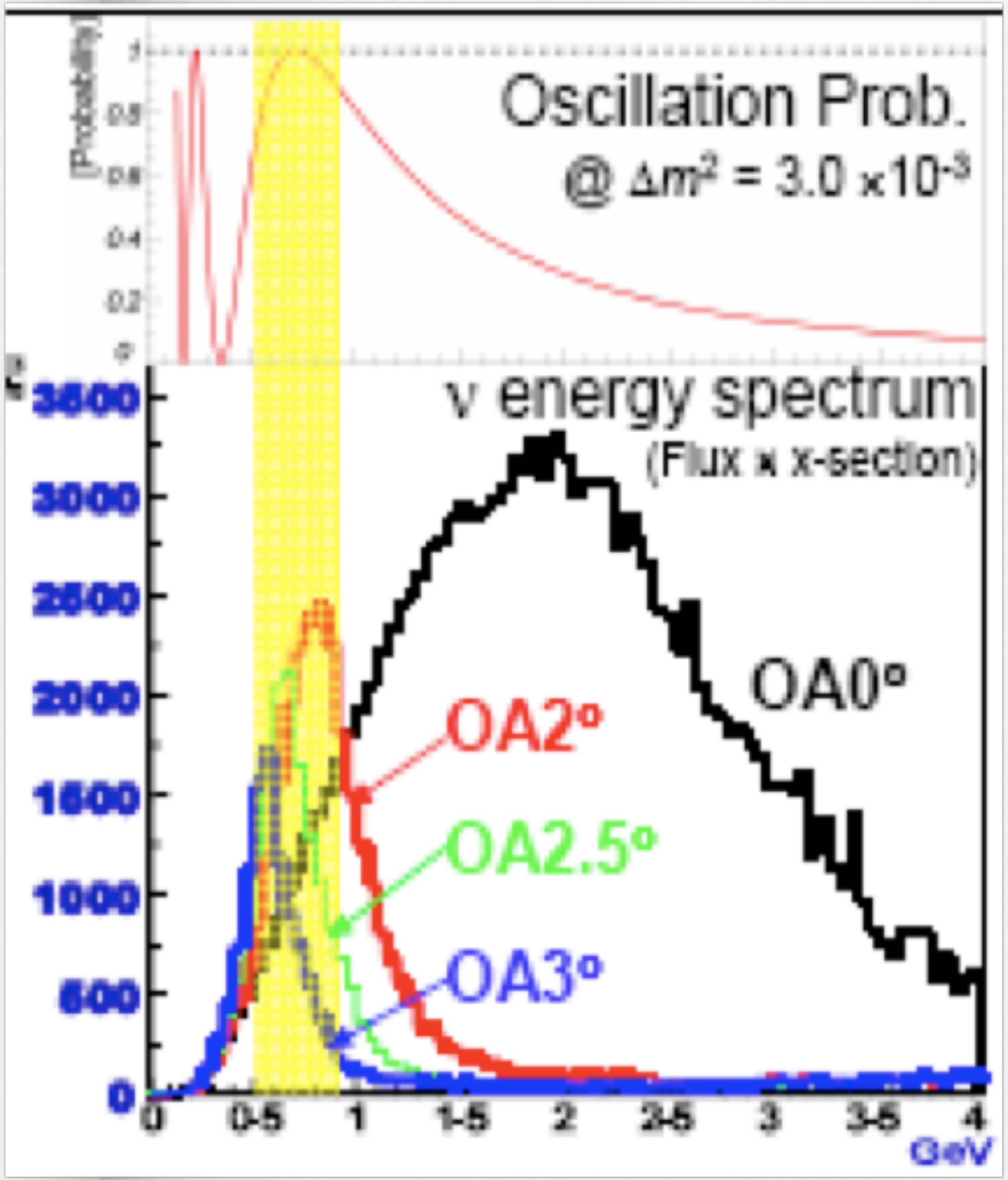
- E_ν reconstruction using CCQE kinematics $\nu_\mu n \rightarrow \mu^- p$

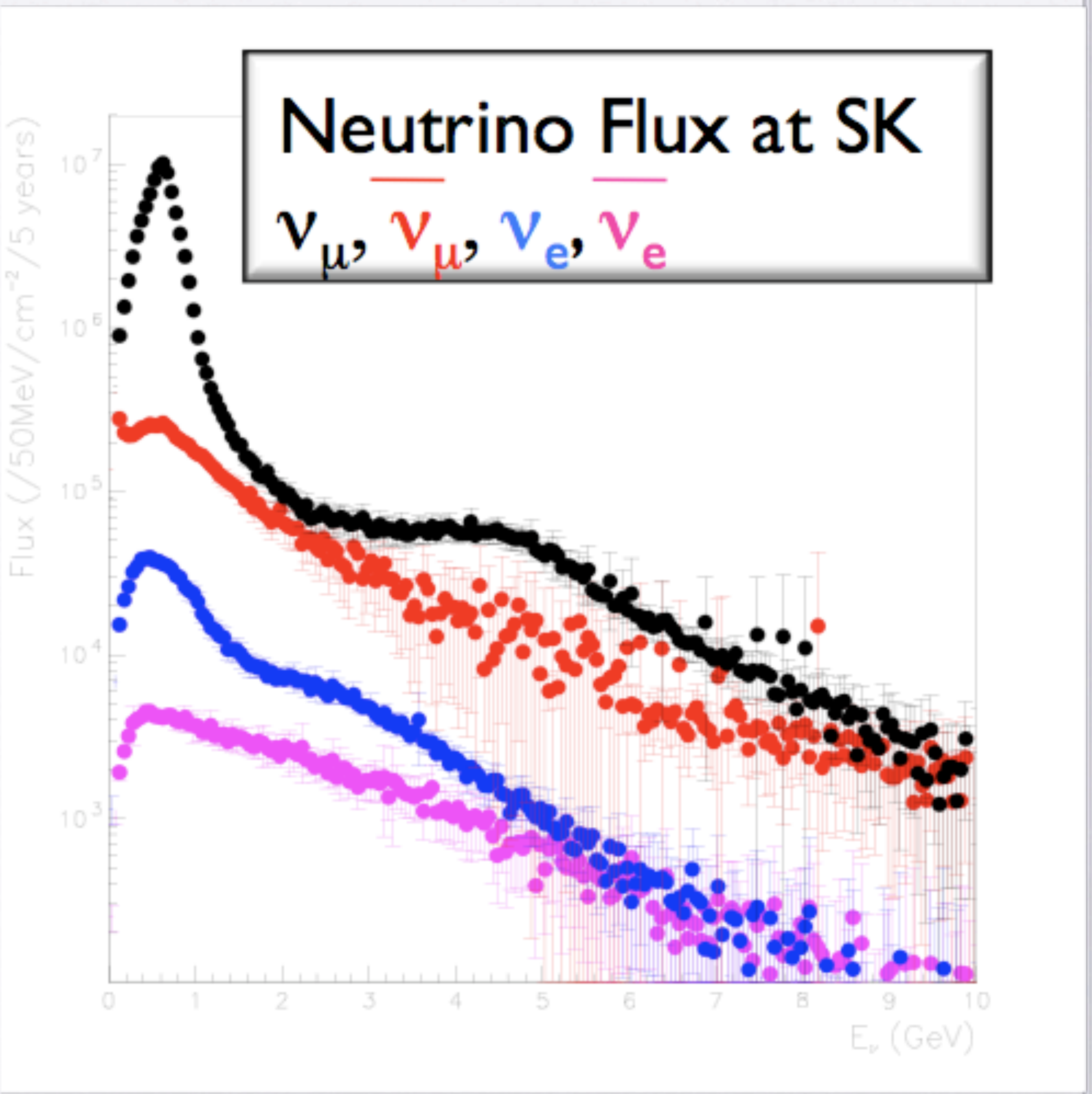
- ν spectrum at SuperK predicted by correction of ν spectrum at Near Detector (ND280m) by Far/Near ratio

- PID at SK
  μ/e identification
  background suppression in ν_e search (K2K)

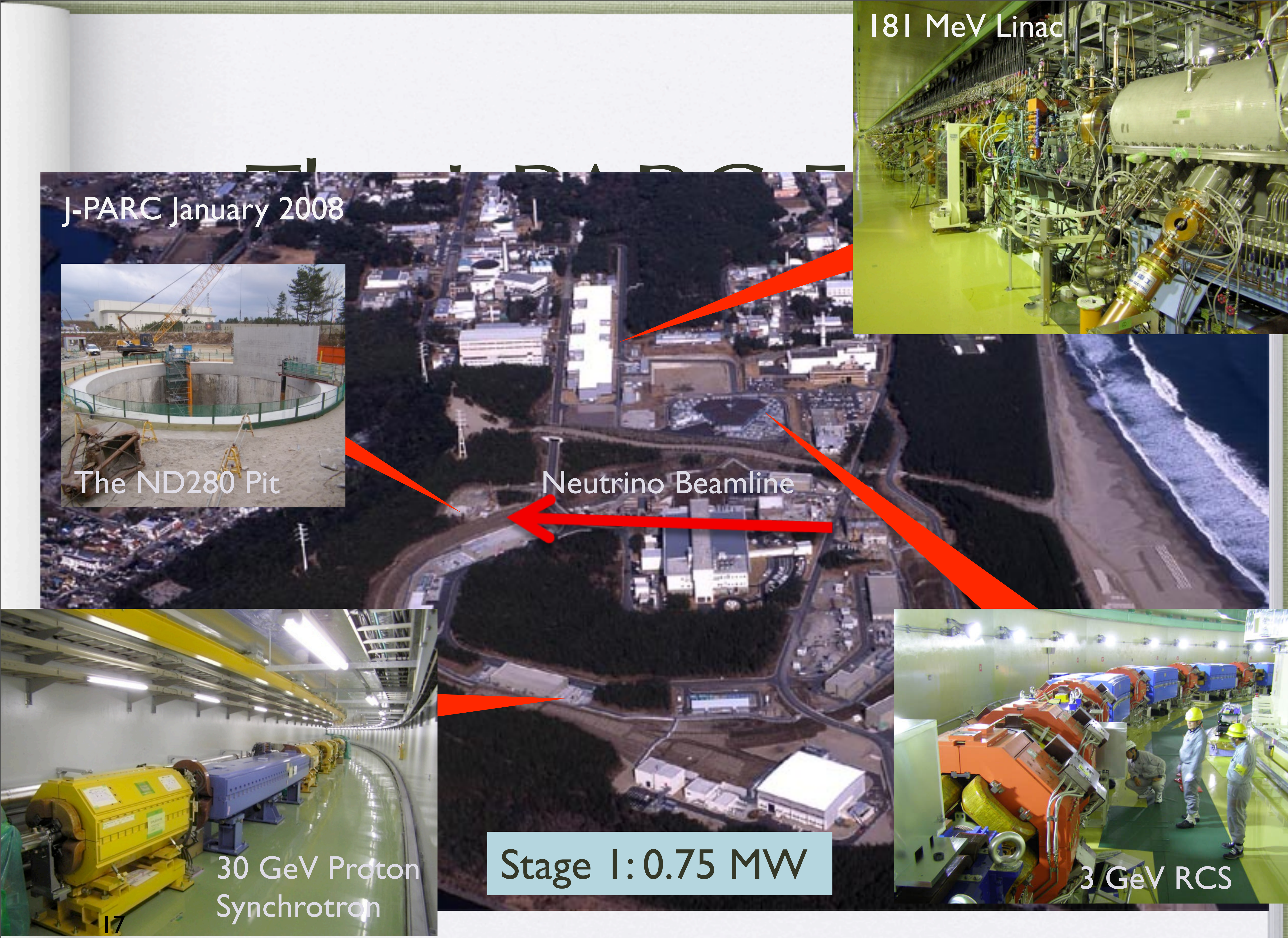


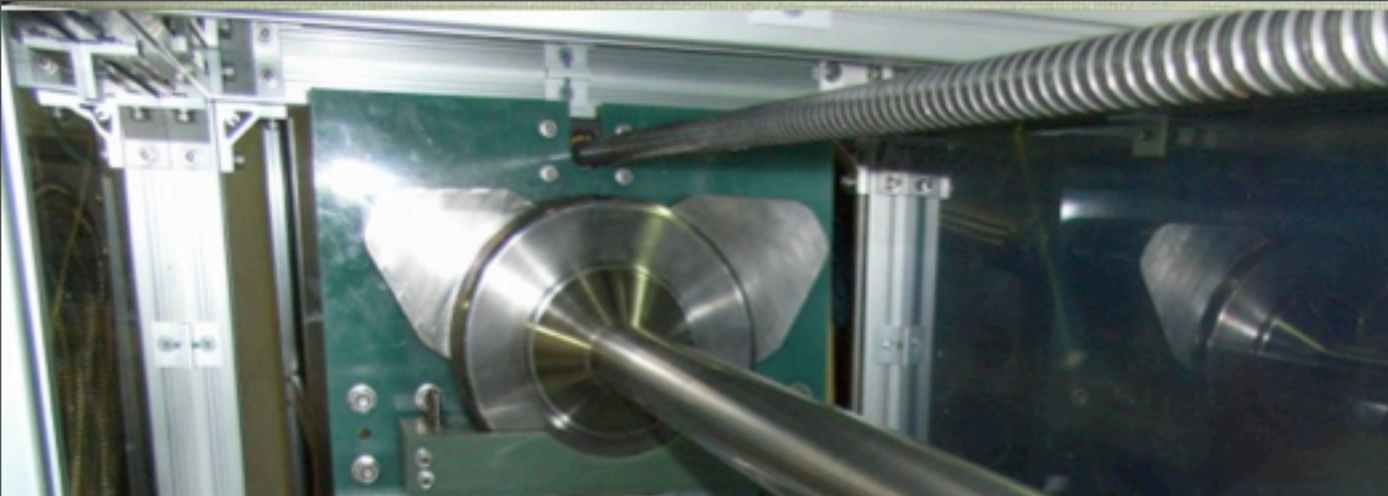
neutrino beam

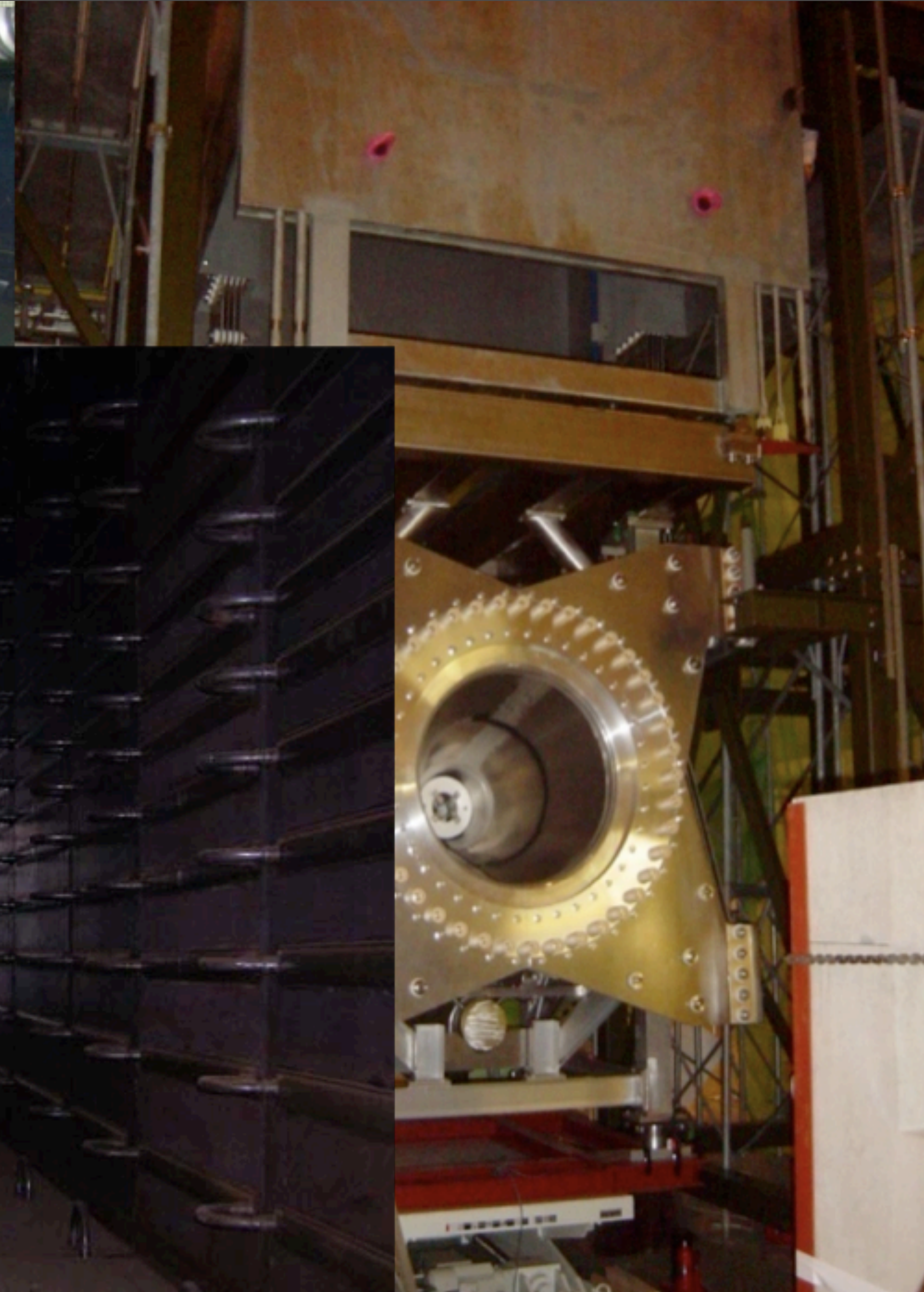




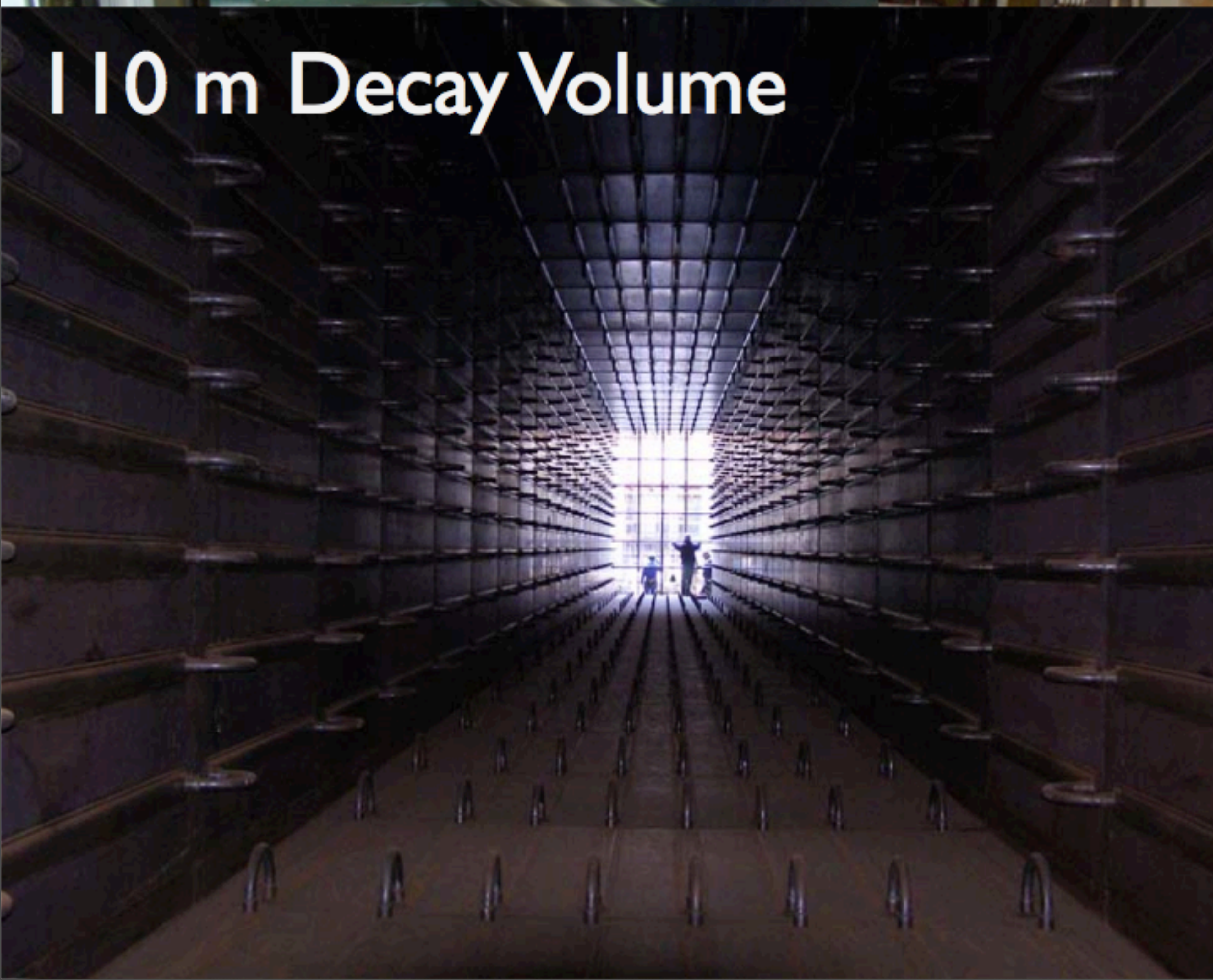
beam composition expected at T2K


181 MeV Linac
J-PARC January 2008
The ND280 Pit
Neutrino Beamline
Stage 1: 0.75 MW
30 GeV Proton
Synchrotron
3 GeV RCS

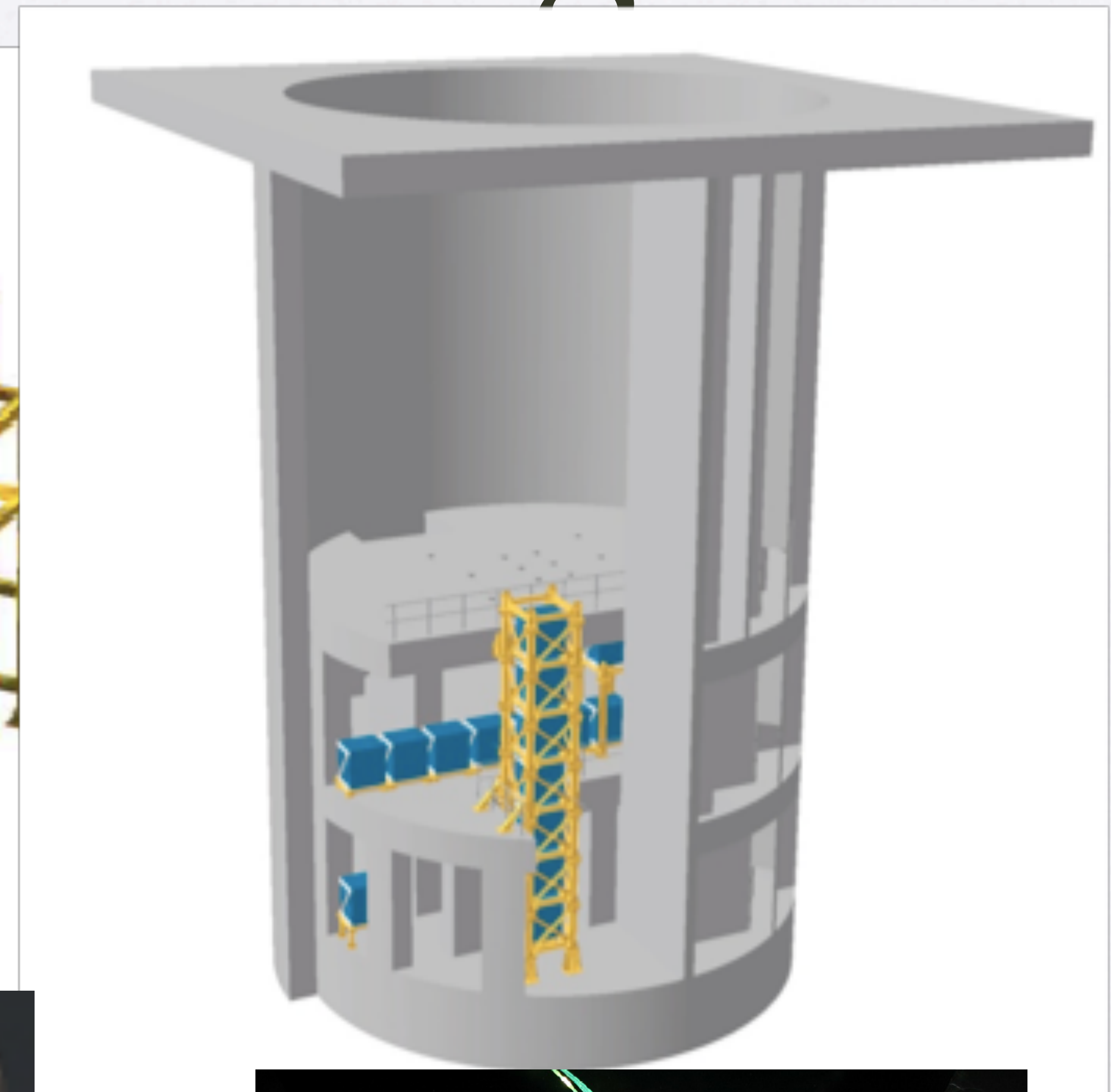


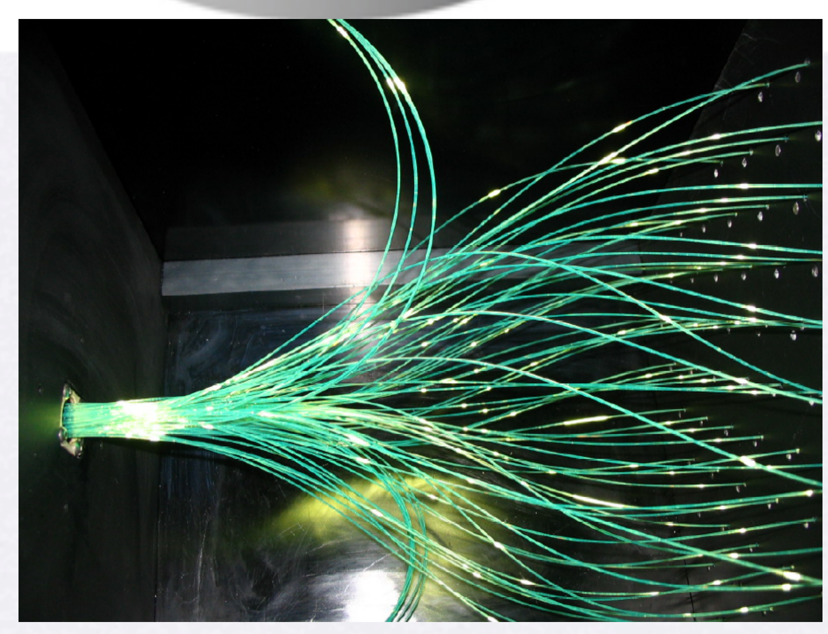


110 m Decay Volume



beam monitor - Ingrid

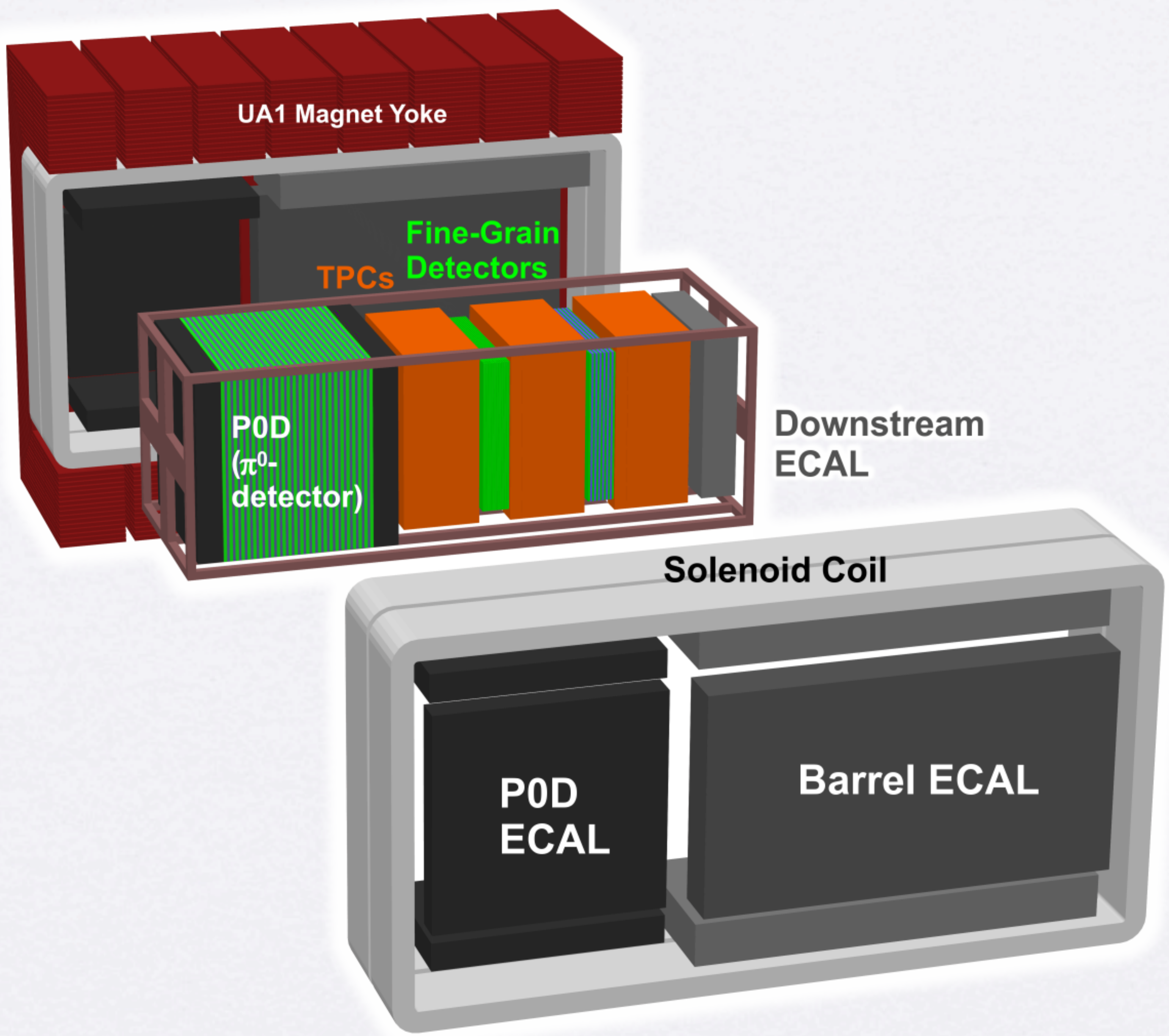




ND280 detector

- Understand the beam to SK
  UA1 Magnet 0.2T field

  Includes a water target
  in both physics regions
  Understand interactions at SK



Fine Grained Detectors
(FGDs) & TPCs
Particle Tracking
ν_μ, ν_e measurements

P0D
Measure NC π^0 rate

ECAL
Surrounds tracker and P0D.
Capture EM energy

SMRD
Muon ranging instrumentation in the magnet yoke

ND280 Magnet


Installation of the coils

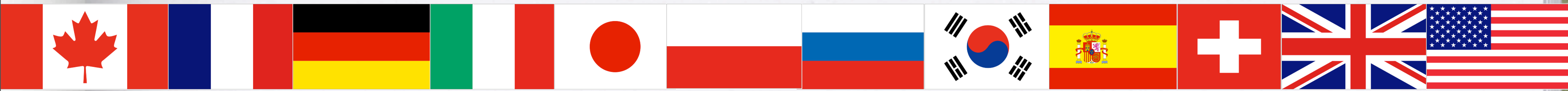

The Magnet Moving System in the Pit


The Magnet at JPARC


Delivery of the basket for testing.

test of electronics
presently going on in Tokai

The T2K Collaboration



385 members, 64 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

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

Switzerland
- U. Bern
- U. Geneva
- ETH Zurich

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

S. Korea
- N. U. Chonnam
- U. Dongshin
- N. U. Gyeongsang
- N. U. Kyungpook
- U. Sejong
- N. U. Seoul
- U. Sungkyunkwan

Spain
- IFIC, Valencia
- U. A. Barcelona

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

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

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

Russia
- INR

Conclusions

- **T2K is on the way to start collecting neutrinos from April 2009**
  - J-PARC facility on schedule
  - SK upgrade finished
  - Construction of ND280 detectors ongoing
- Stay tuned