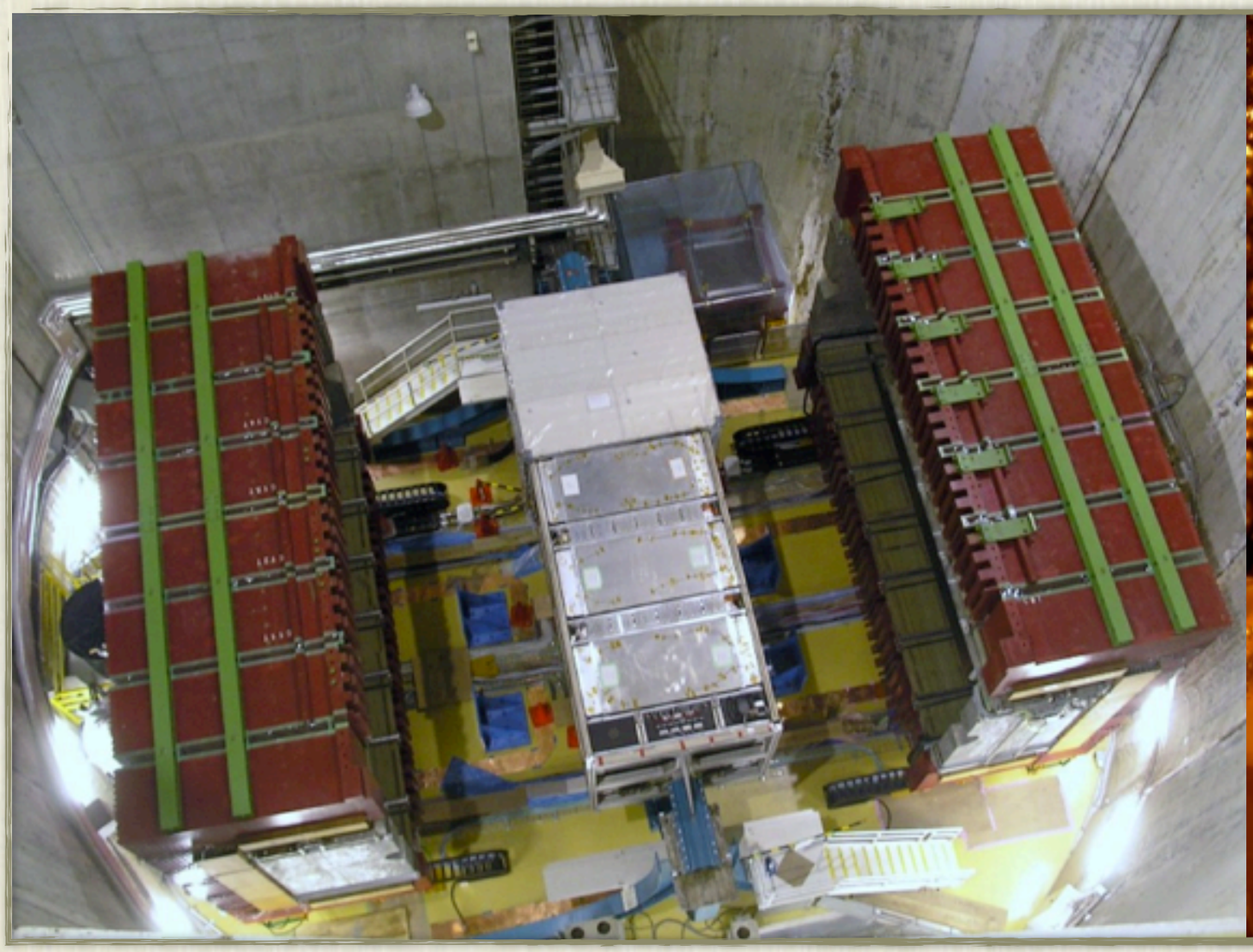
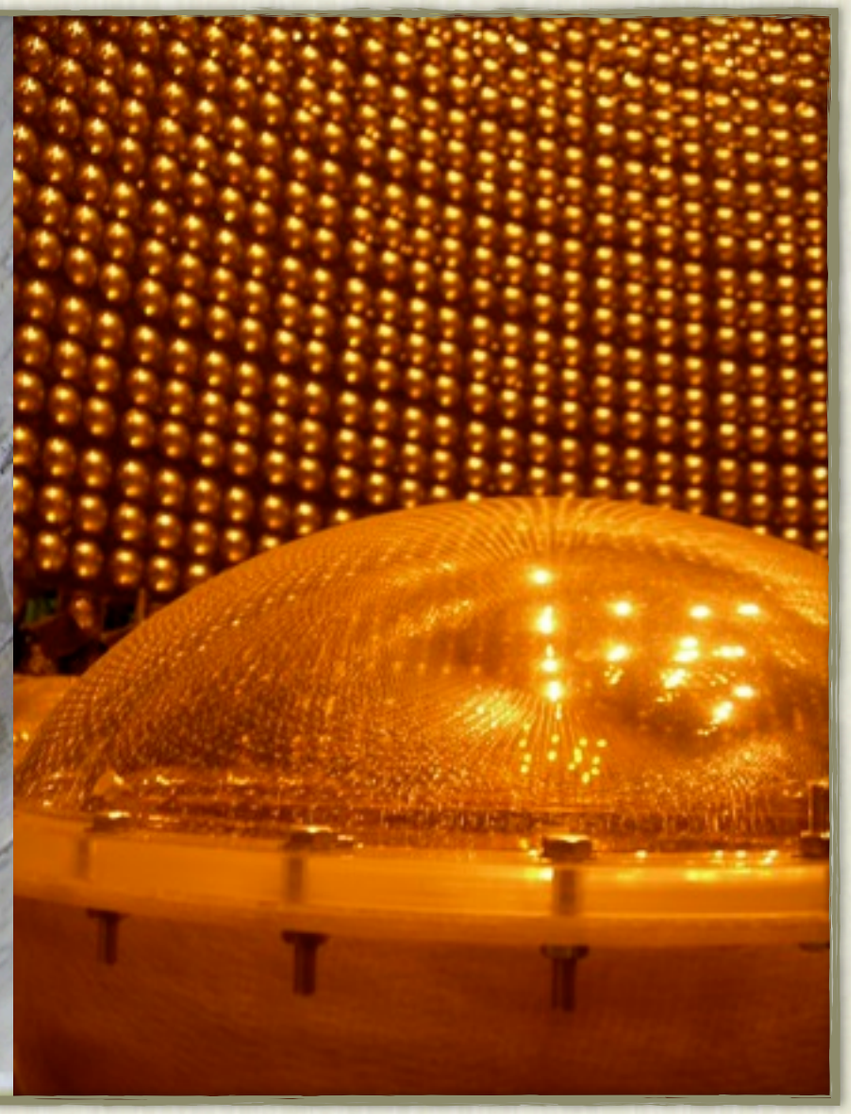




# T2K Status

*Fanny Dufour, Geneva University, for the T2K collaboration*

# Outline

The T2K experiment

Current status of the beam

Current status of ND280

Current status SK

# The collaboration

~500 members, 61 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

**Italy**
INFN, U. Roma
INFN, U. Napoli
INFN, U. Padova
INFN, U. Bari

**Japan**
ICRR Kamioka
ICRR RCCN
KEK
Kobe U.
Kyoto U.
Miyagi U. Edu.
Osaka City U.
U. Tokyo

**Poland**
A. Soltan, Warsaw
H.Niewodniczanski, Cracow
T. U. Warsaw
U. Silesia, Katowice
U. Warsaw
U. Wroclaw

**Russia**
INR

**S. Korea**
N. U. Chonnam
U. Dongshin
U. Sejong
N. U. Seoul
U. Sungkyunkwan

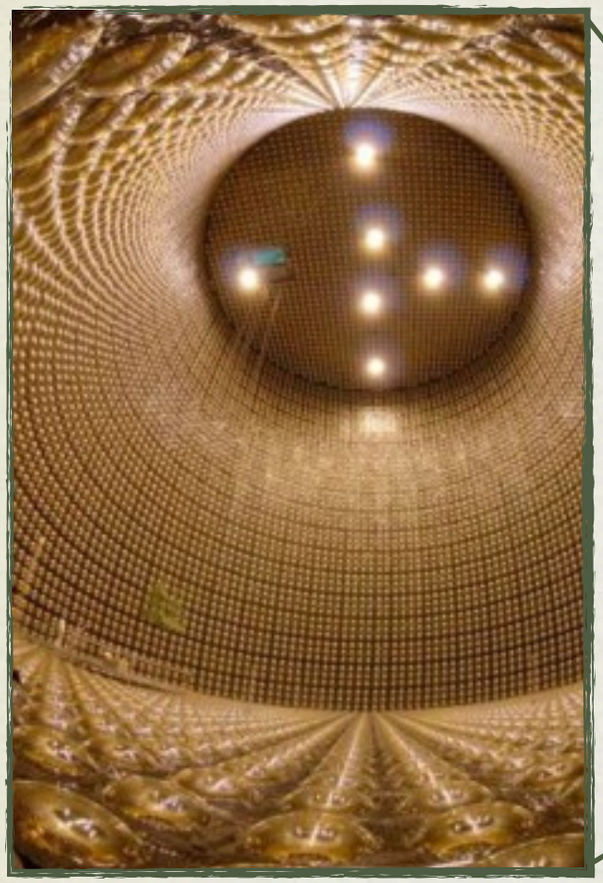
**Spain**
IFIC, Valencia
U. A. Barcelona

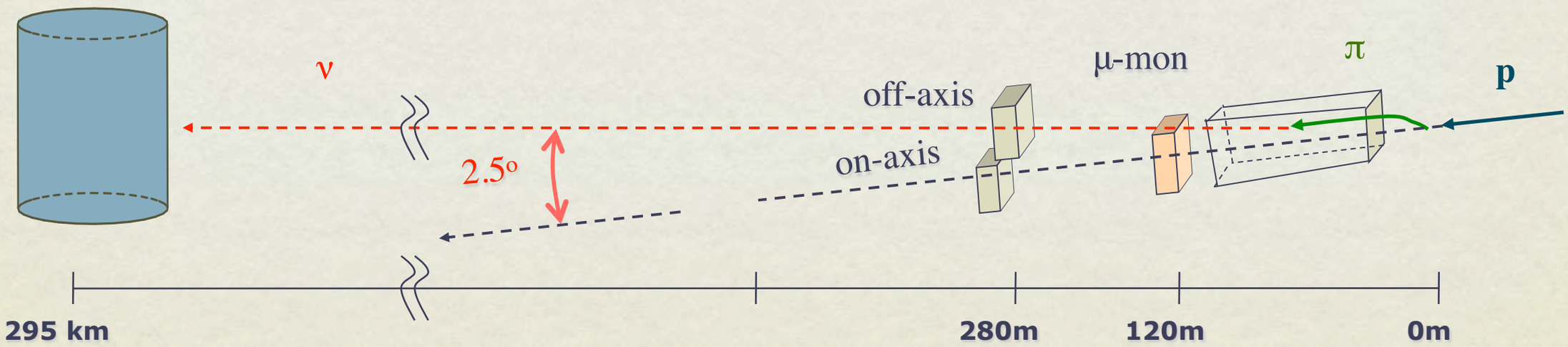
**Switzerland**
U. Bern
U. Geneva
ETH Zurich

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

**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

# Overview of the experiment



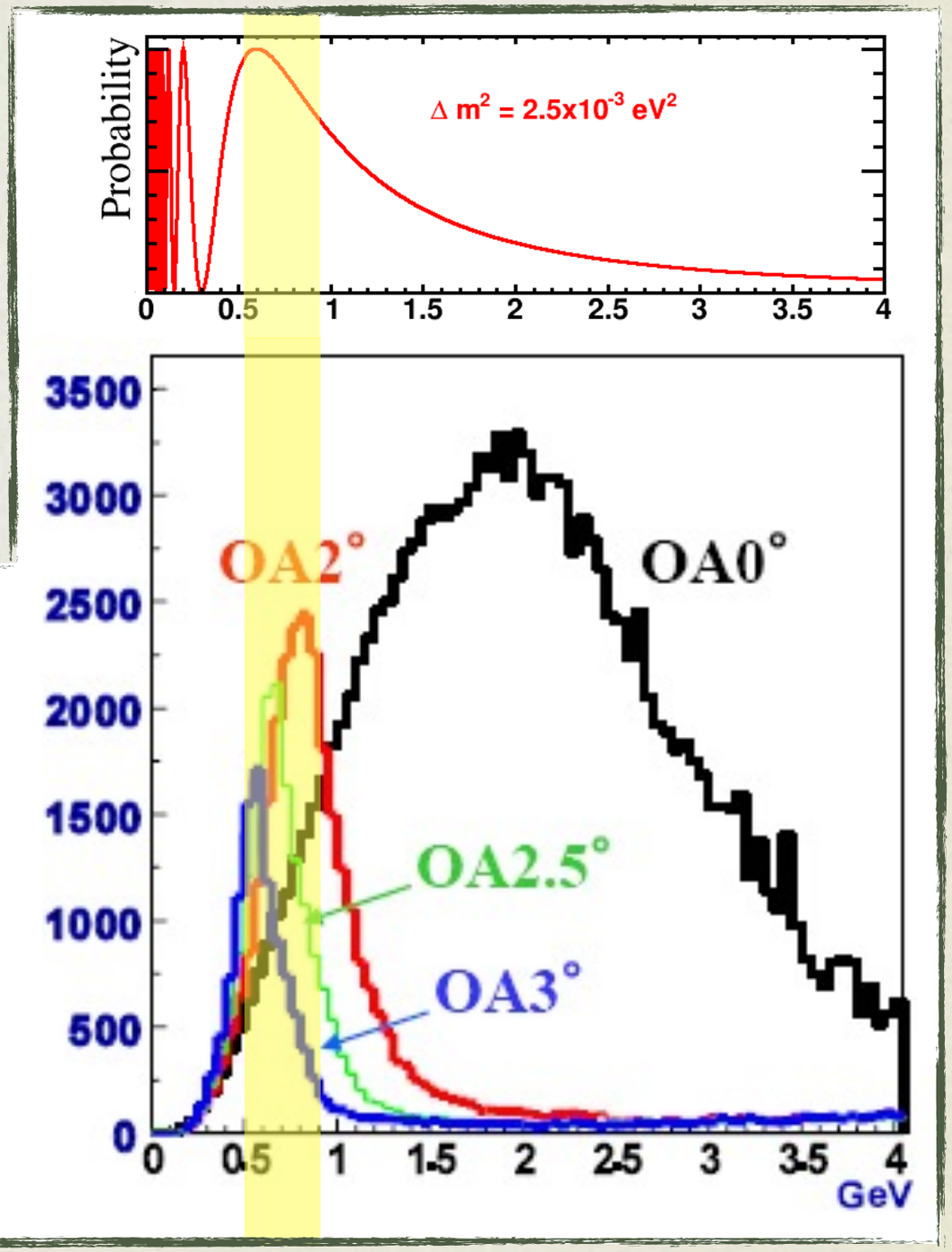


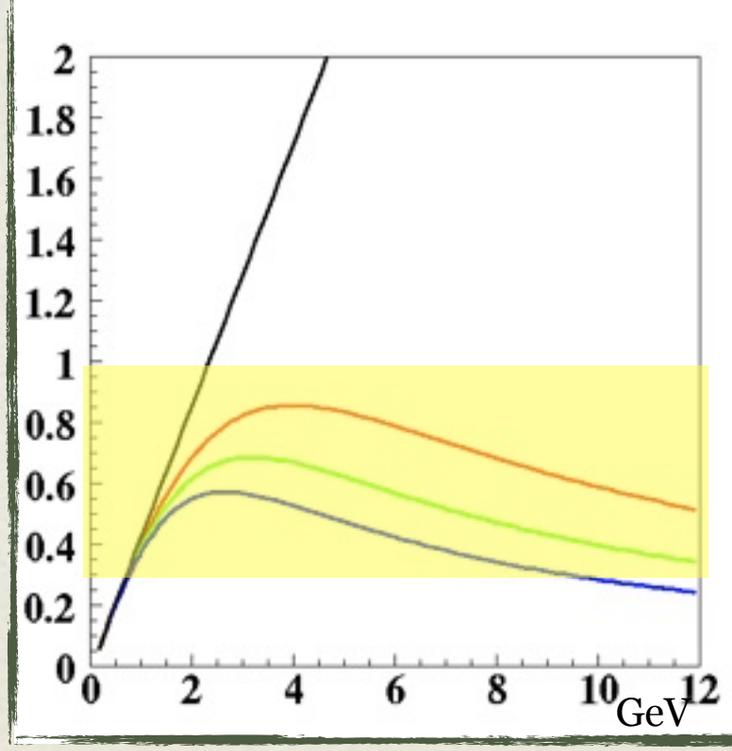
# Off-axis principle

Detector is 2.5° off-axis

→ Narrow beam

→ Most of the flux is at the optimal energy for measuring oscillation

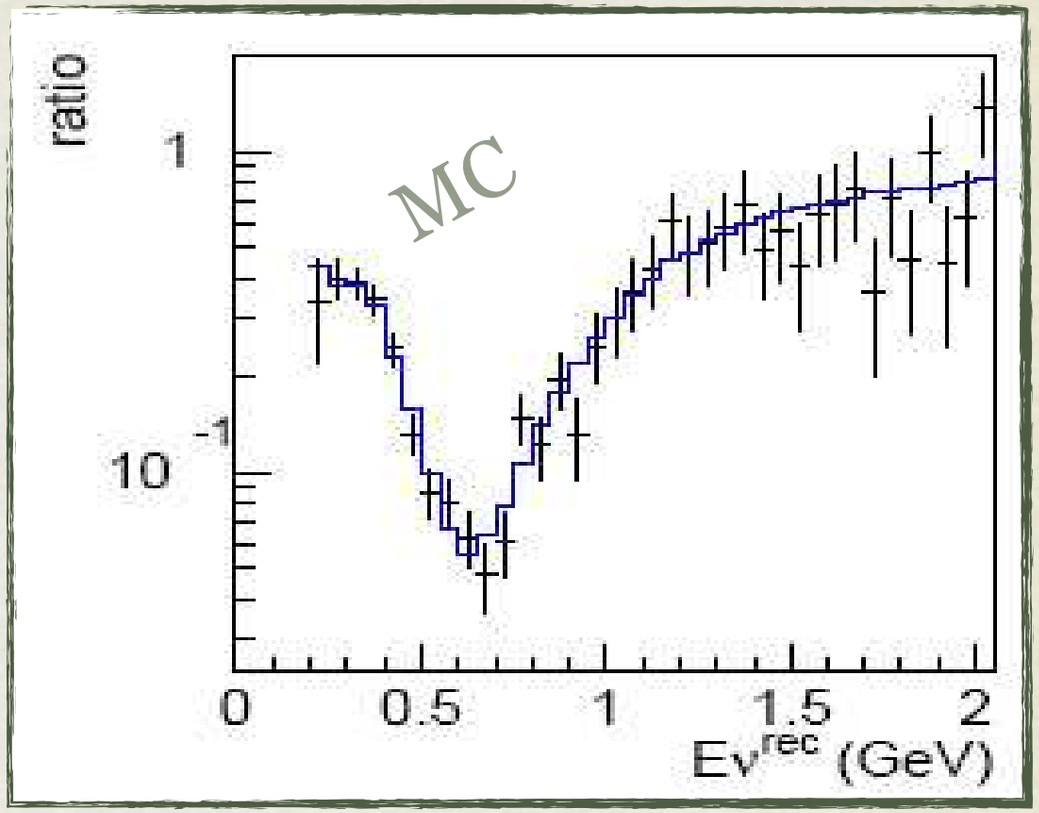


# Physics goals (1): Neutrino oscillations

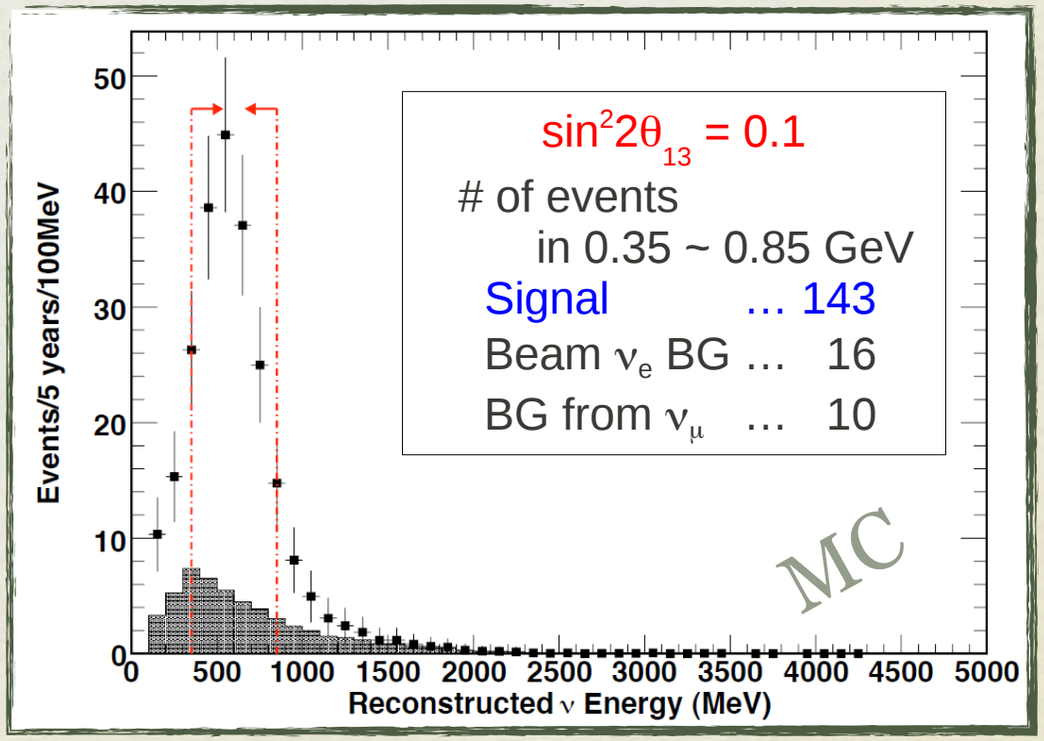
## Disappearance measurement: $\nu_\mu \rightarrow \nu_\mu$

$$P(\nu_\mu \rightarrow \nu_\mu) \approx 1.0 - (\sin^2(2\theta_{23}) \sin^2(\frac{\Delta m^2_{23} L}{4E})$$

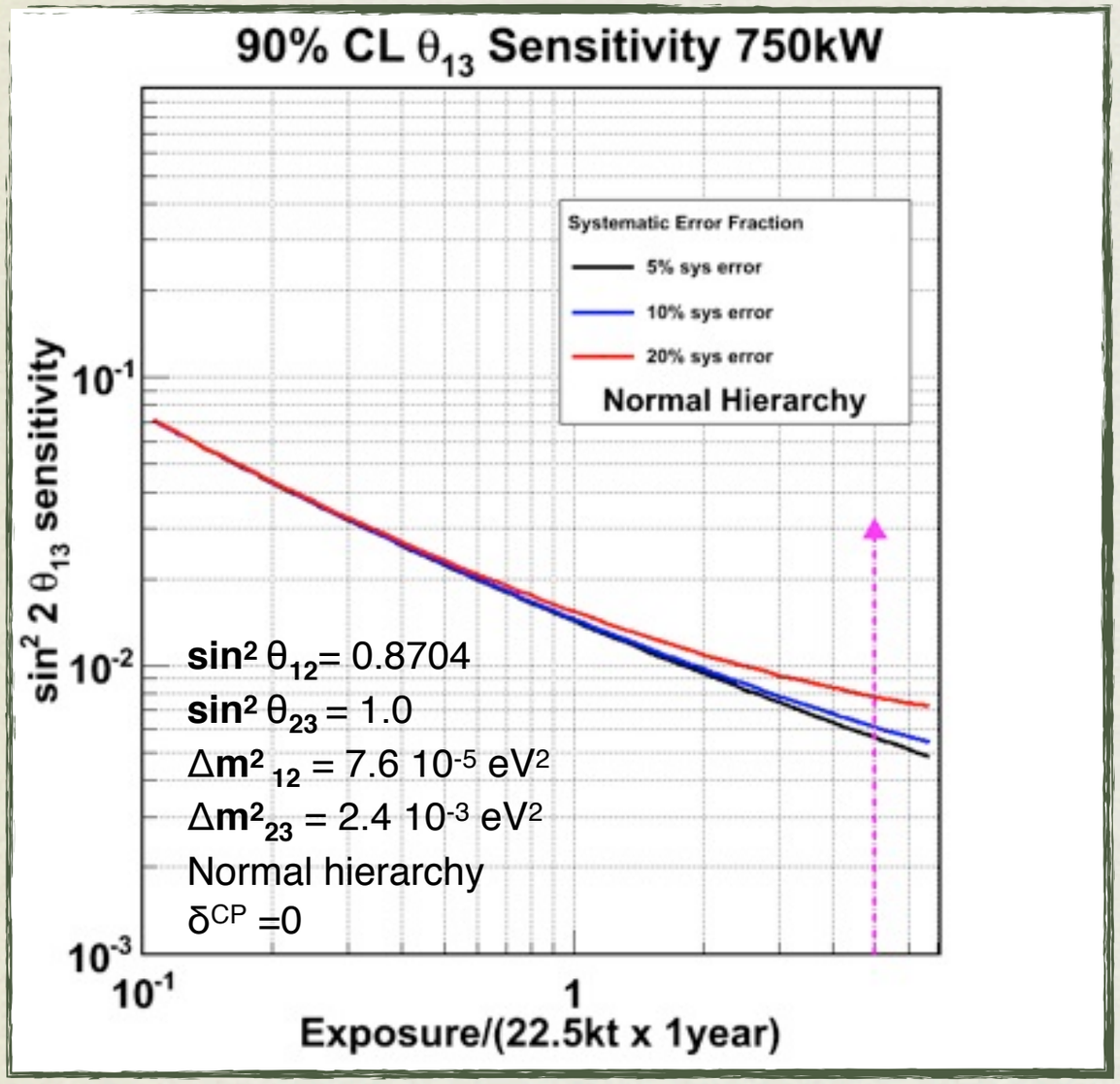


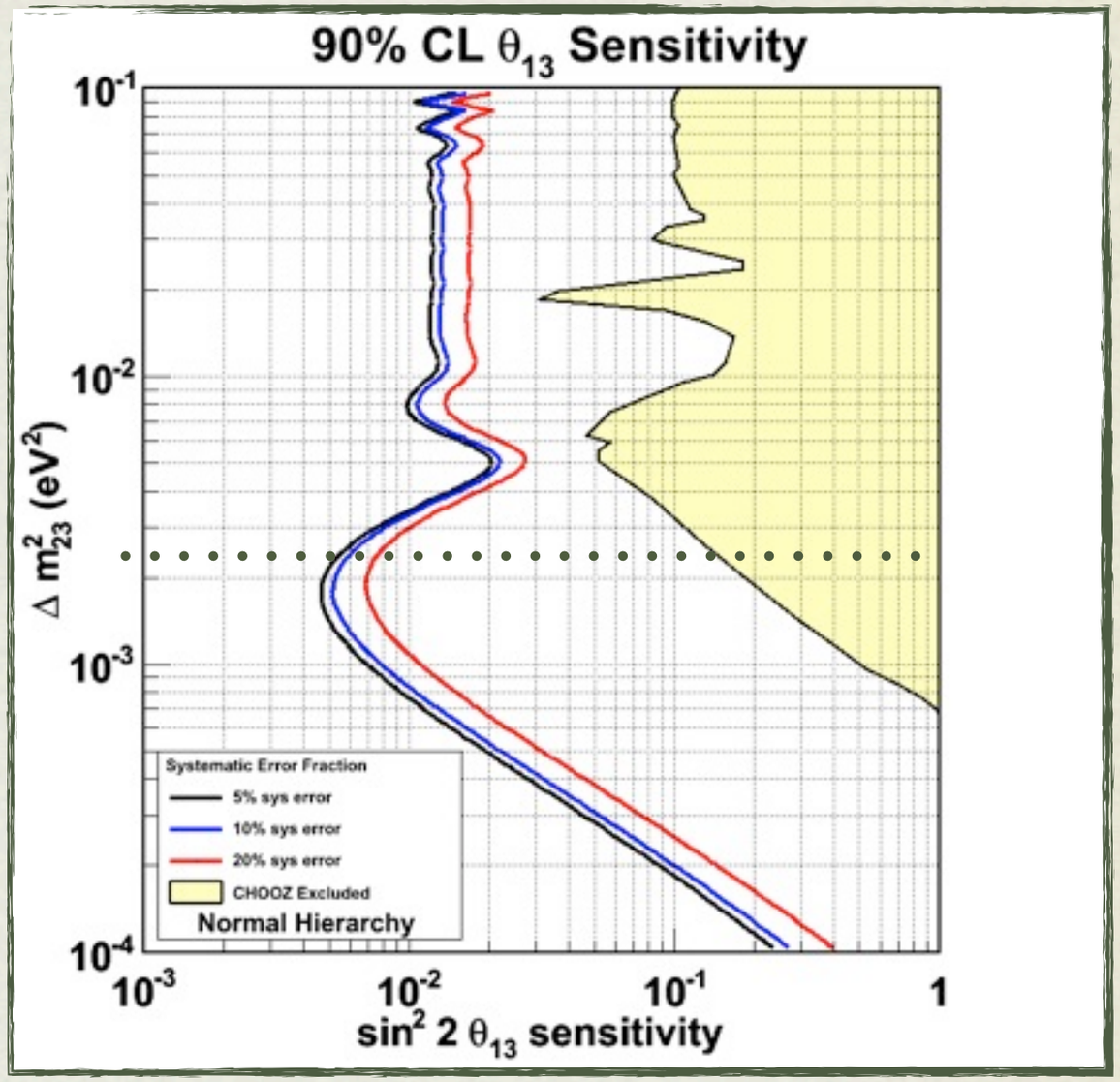

## Appearance measurement: $\nu_\mu \rightarrow \nu_e$

$$P(\nu_\mu \rightarrow \nu_e) \approx \left( \sin^2(\theta_{23}) \sin^2(2\theta_{31}) \right) \sin^2(\frac{\Delta m^2_{23} L}{4E})$$



# Sensitivity to $\theta_{13}$



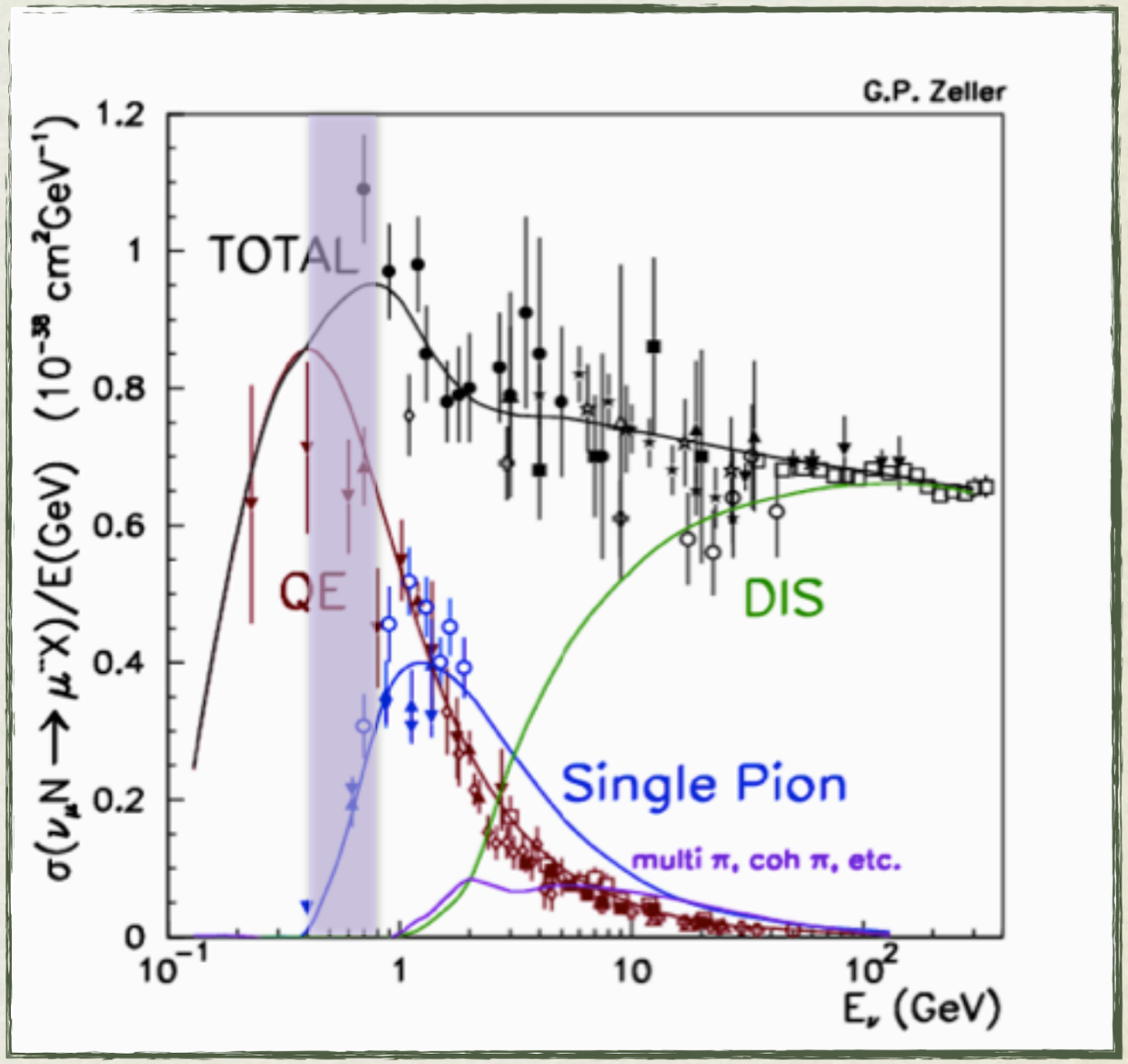




90% C.L. 750kW X 5 years X 22.5 kton fid.

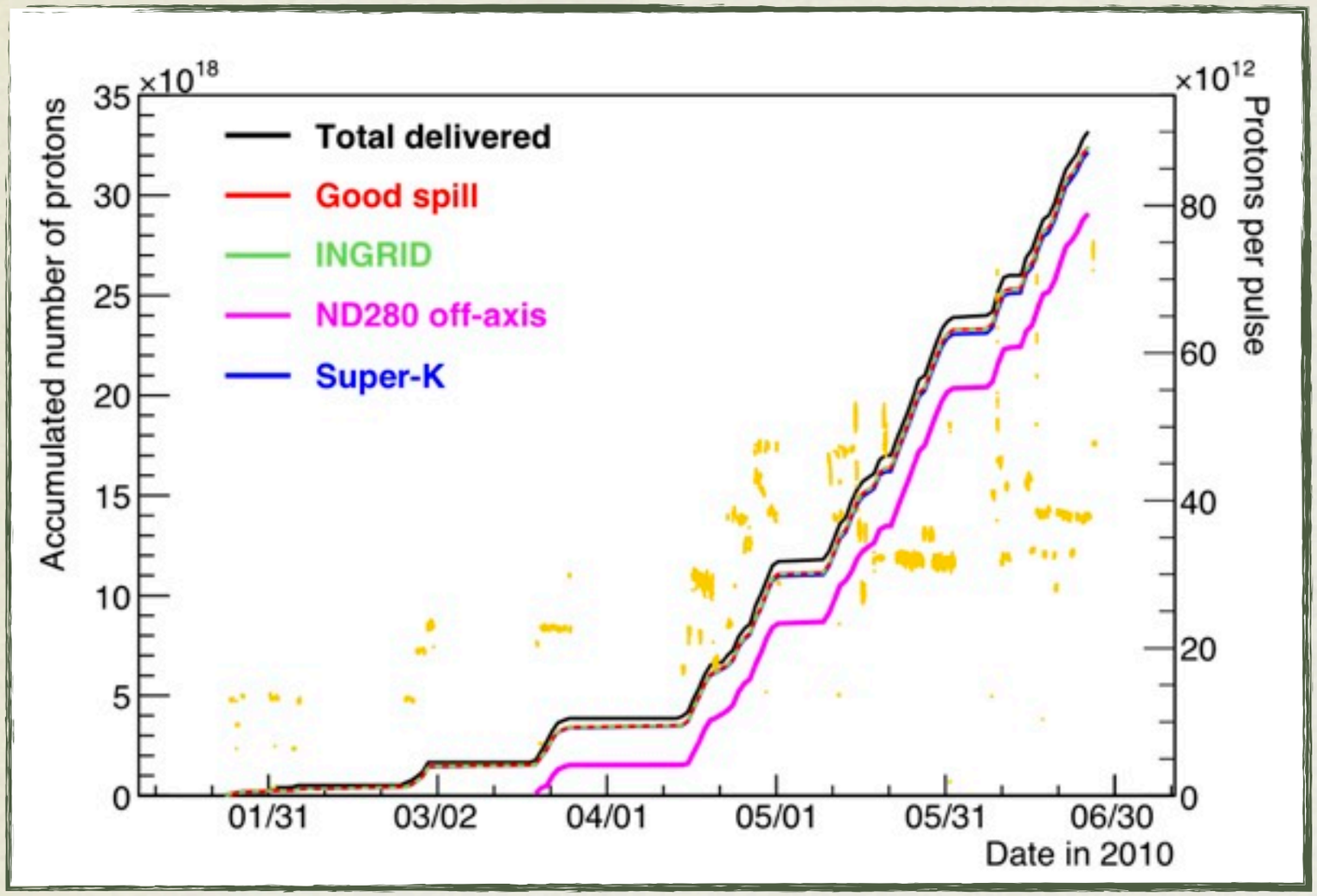
= 8.3 x $10^{21}$ POT

# Physics goals (2): Cross-section measurements

Several cross-section measurements at energies around 600 MeV will be performed with the near detector.



# Proton on target collected in 2010



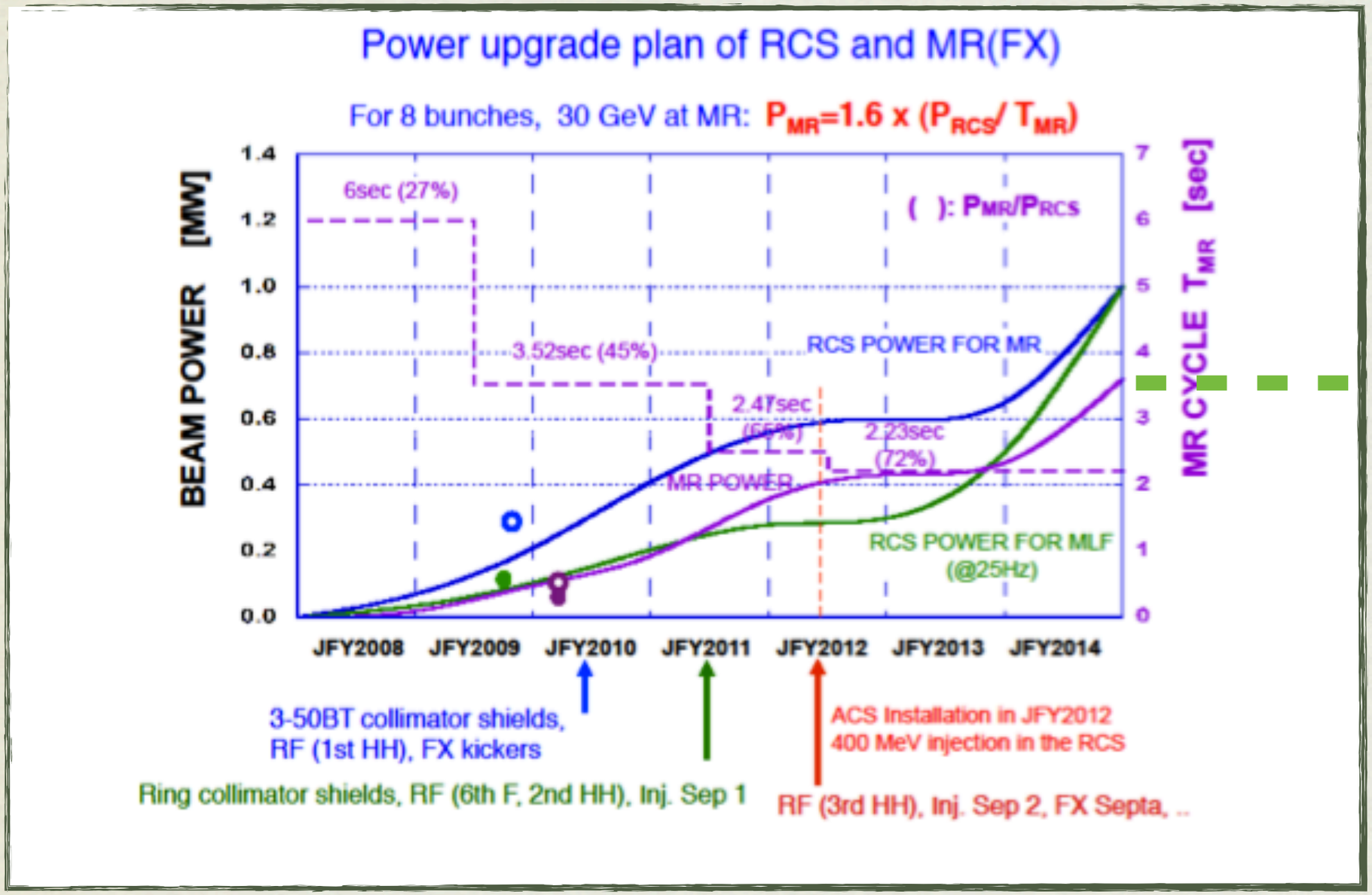

Present limitations :
extraction kickers → changed to faster ones in summer 2010

Radiation issues → go slow, work on collimation

First T2K run completed (January to June 2010)

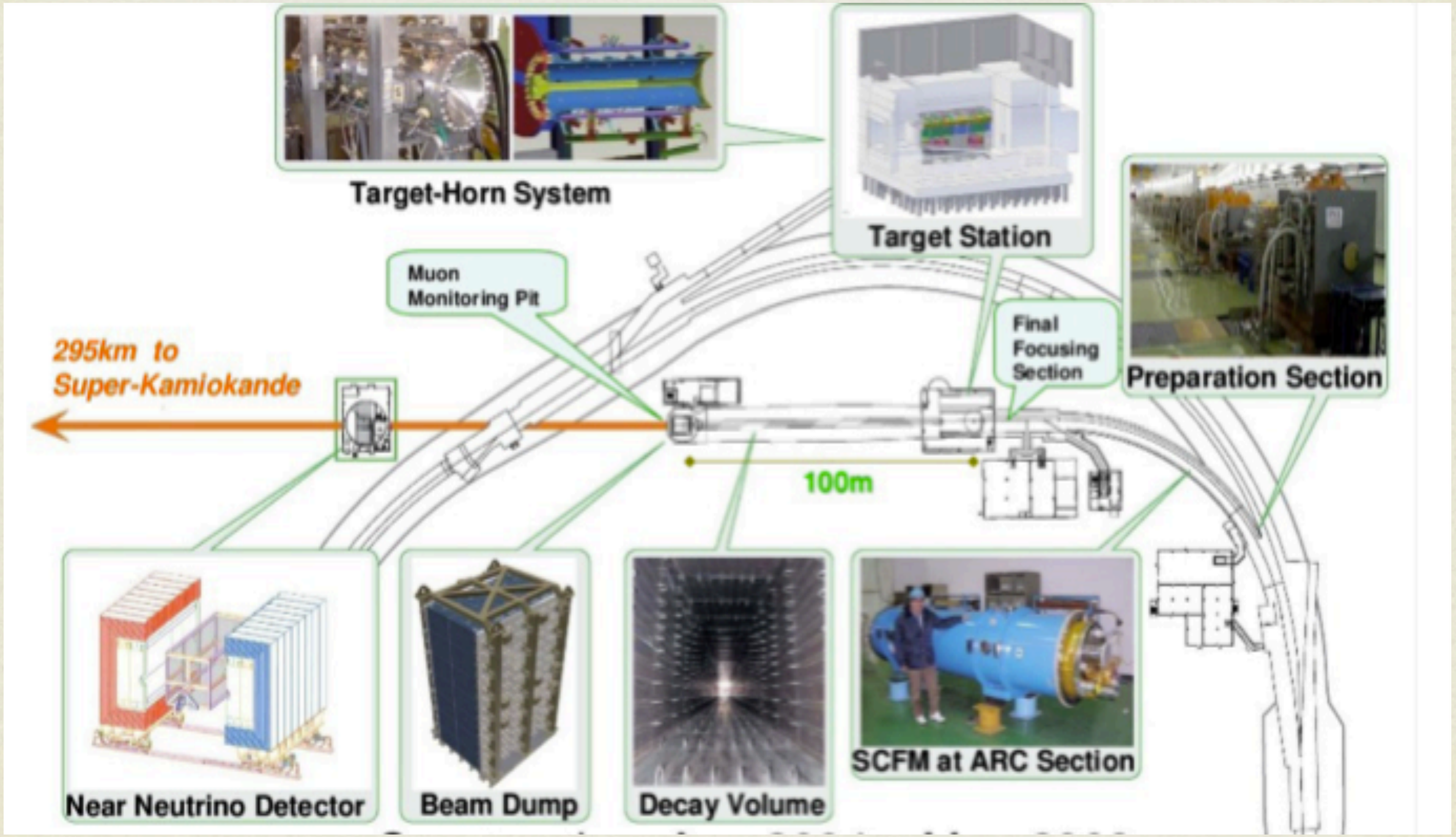
- $3.3 \times 10^{19}$ protons @ 30 GeV for T2K analysis
- 50 kW stable operation with trials at 100 kW
- Super-K live fraction in excess of 99%
- 2011 aim: accumulate 150 kW $\times 10^7$ sec by July 2011

# Upgrade plan




**750 kW in 2014**

# Beamline overview



# ND280 overview

**On-axis detector:**

INGRID

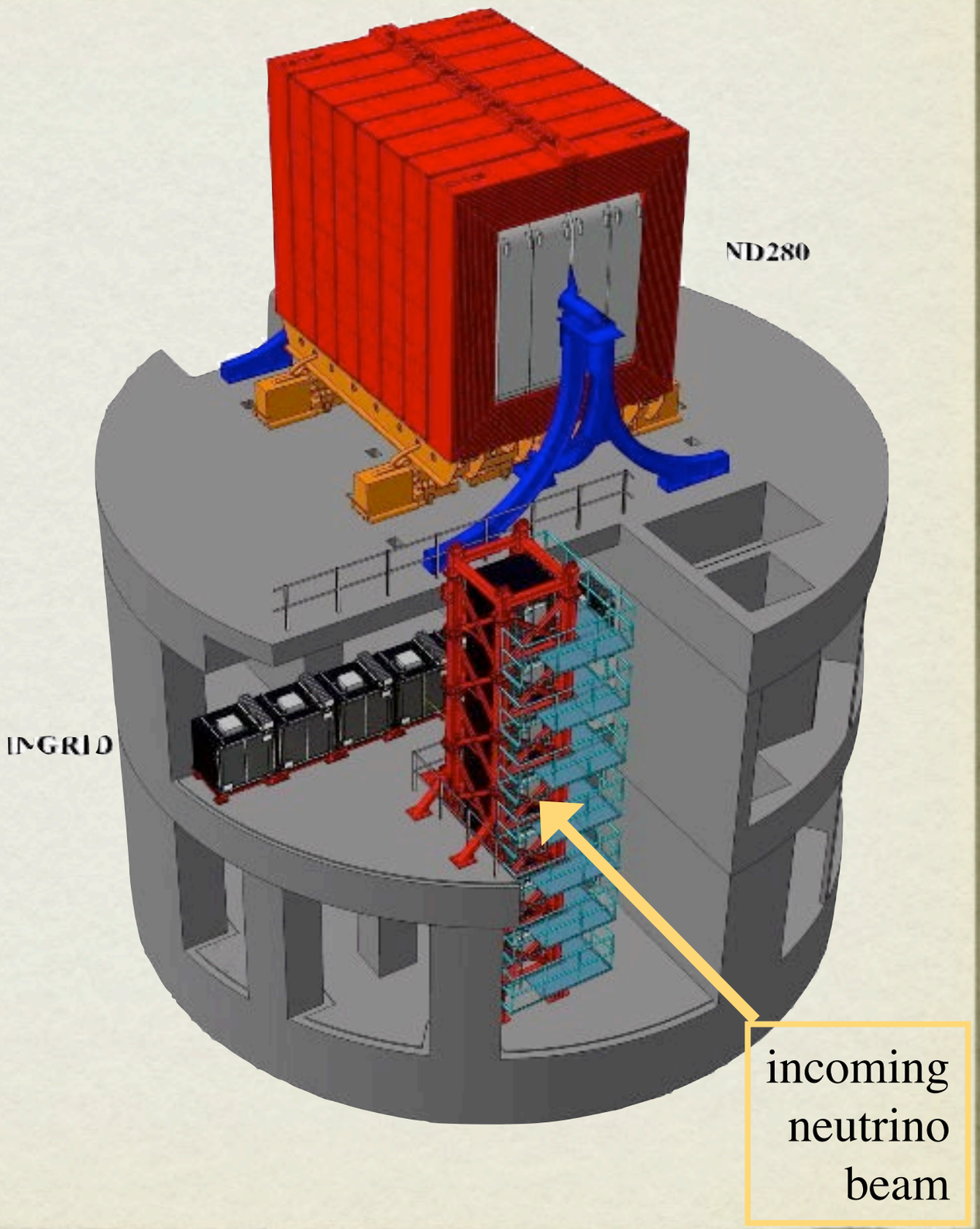
**Off-axis detector:**

tracker: FGD +TPC

P0D

ECAL (downstream and barrel)

SMRD

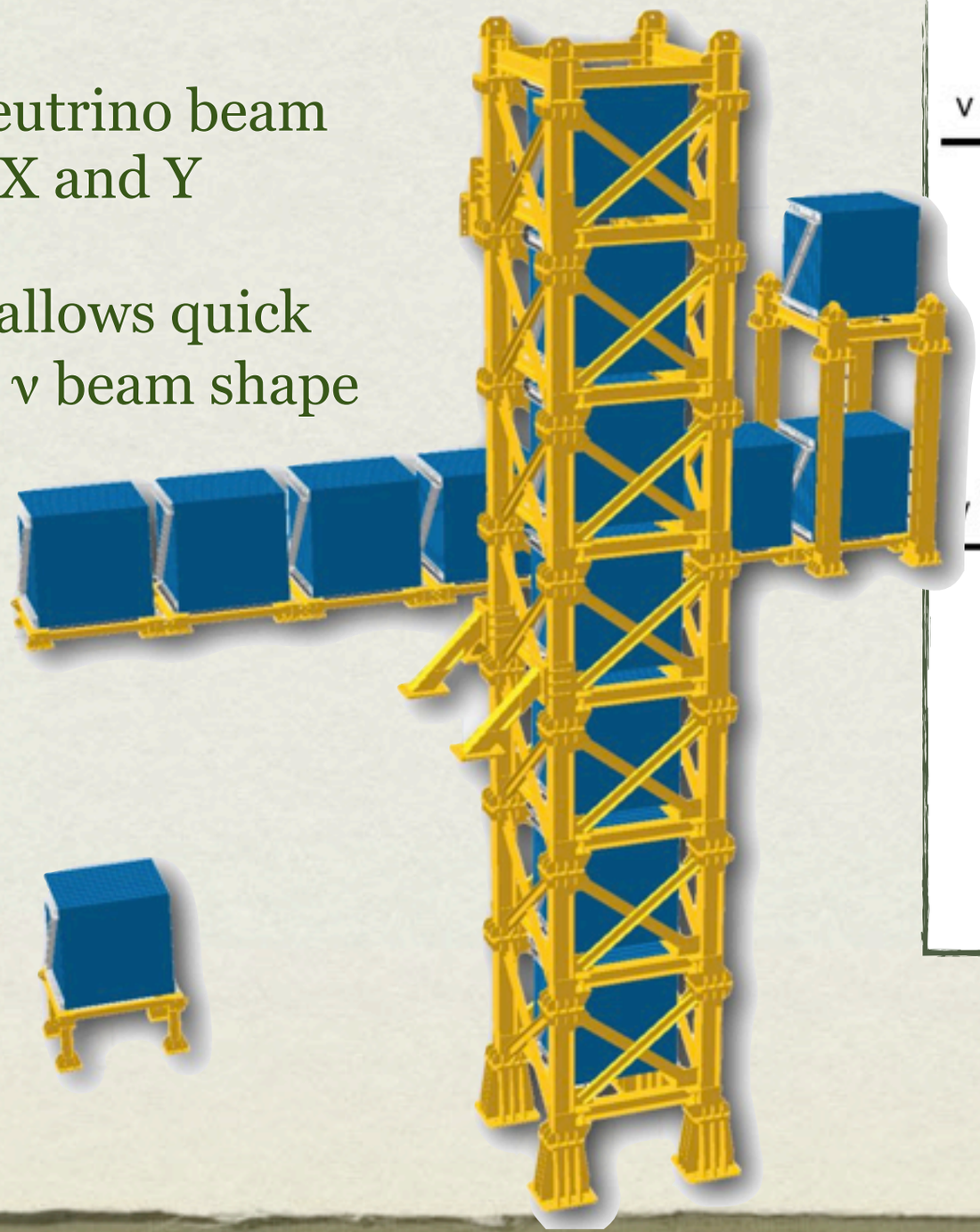


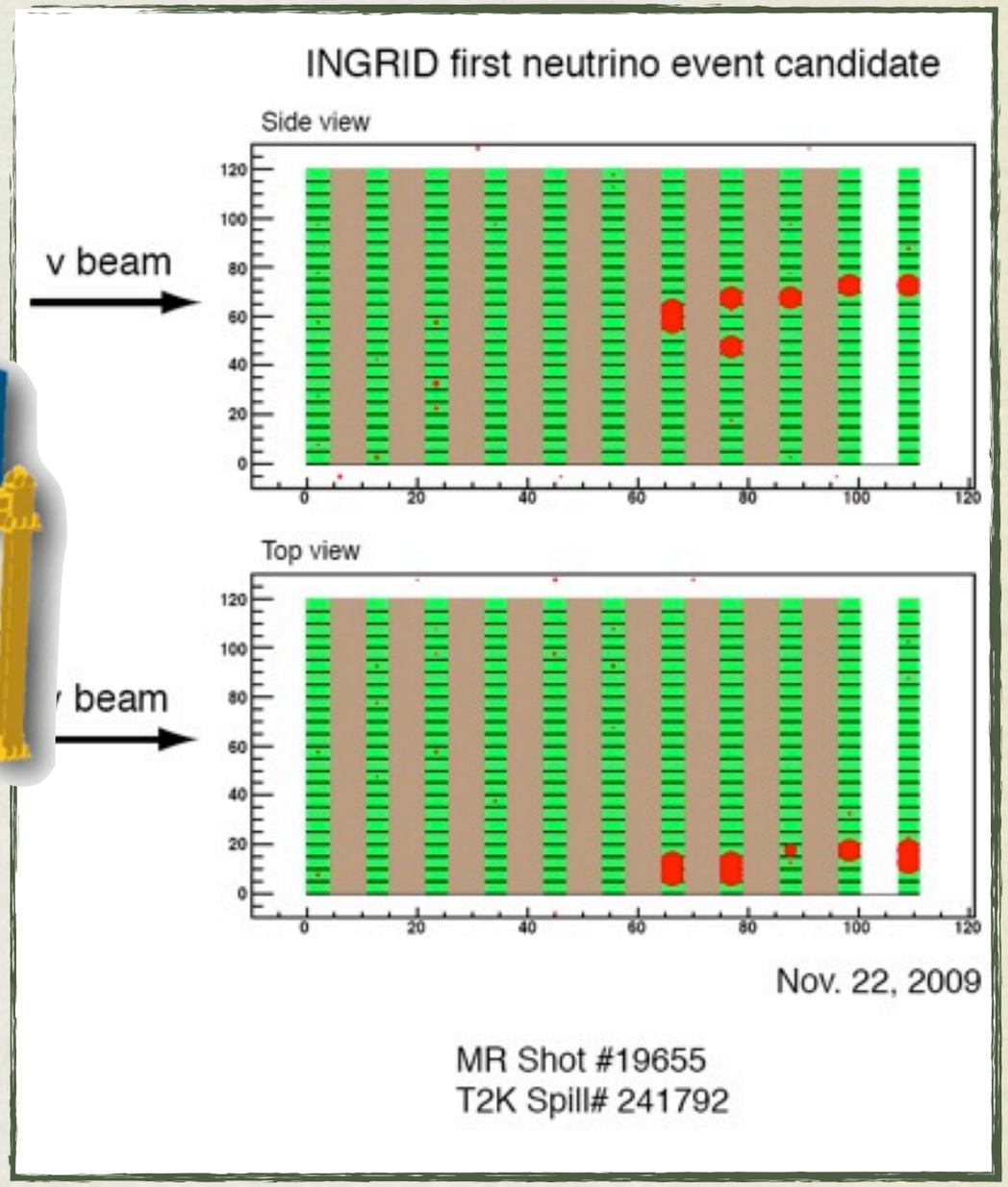
# ND280 on-axis detector: INGRID

Consists of 16 modules of scintillator/iron sandwich planes

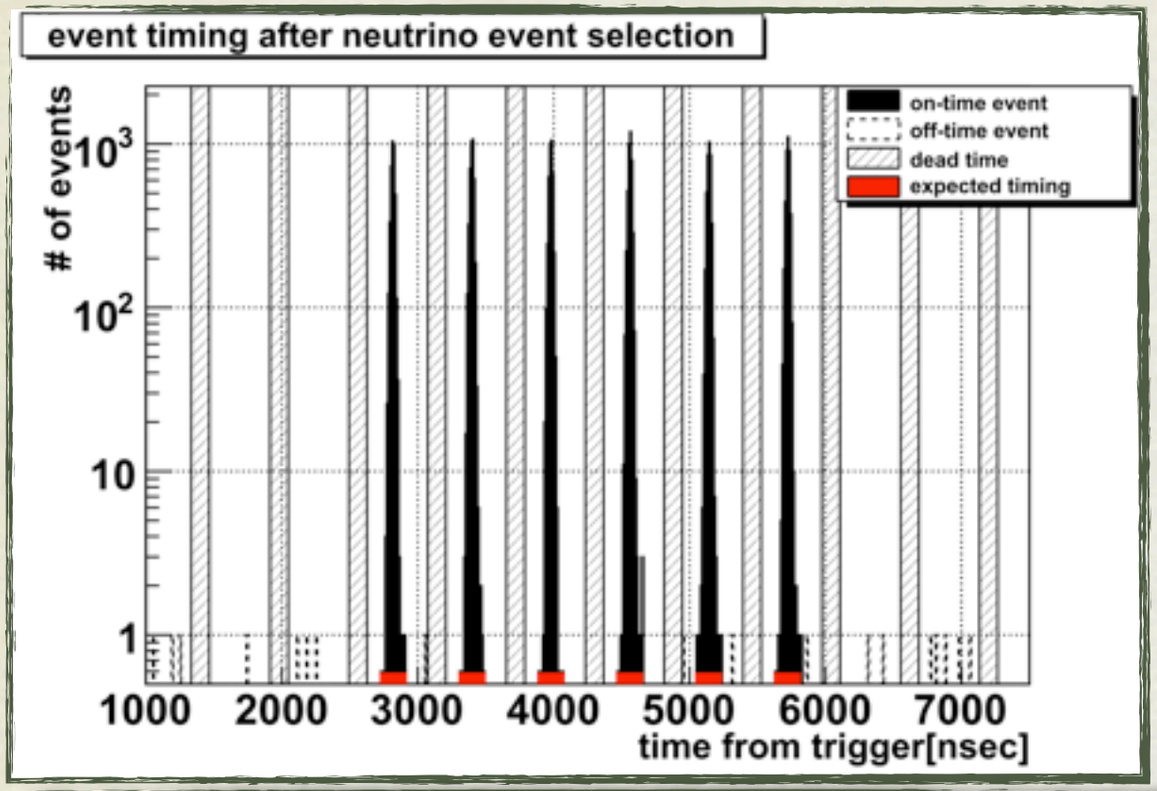
Measures neutrino beam profile in X and Y

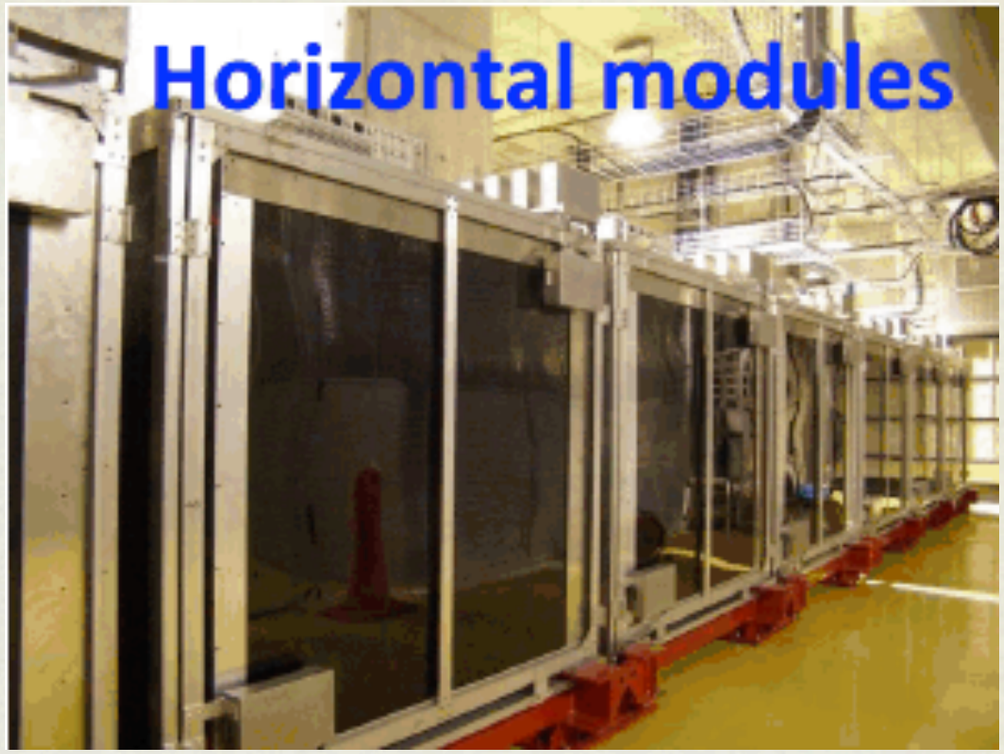
Large mass allows quick feedback on ν beam shape

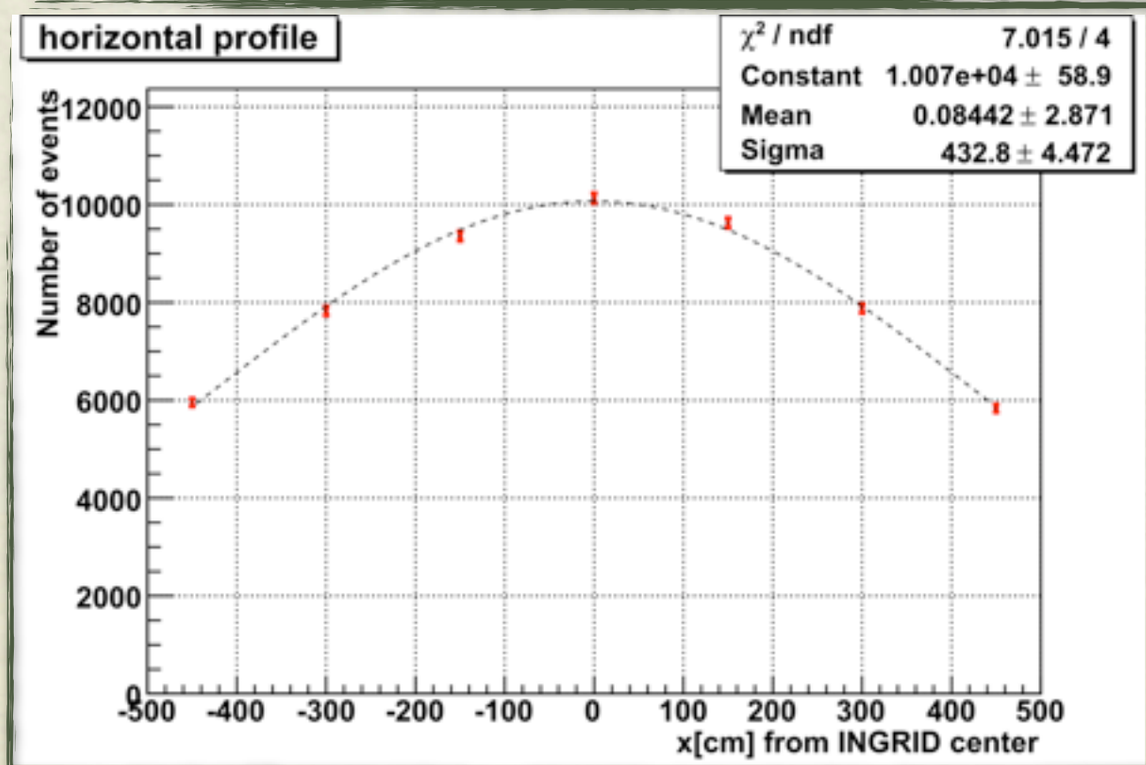


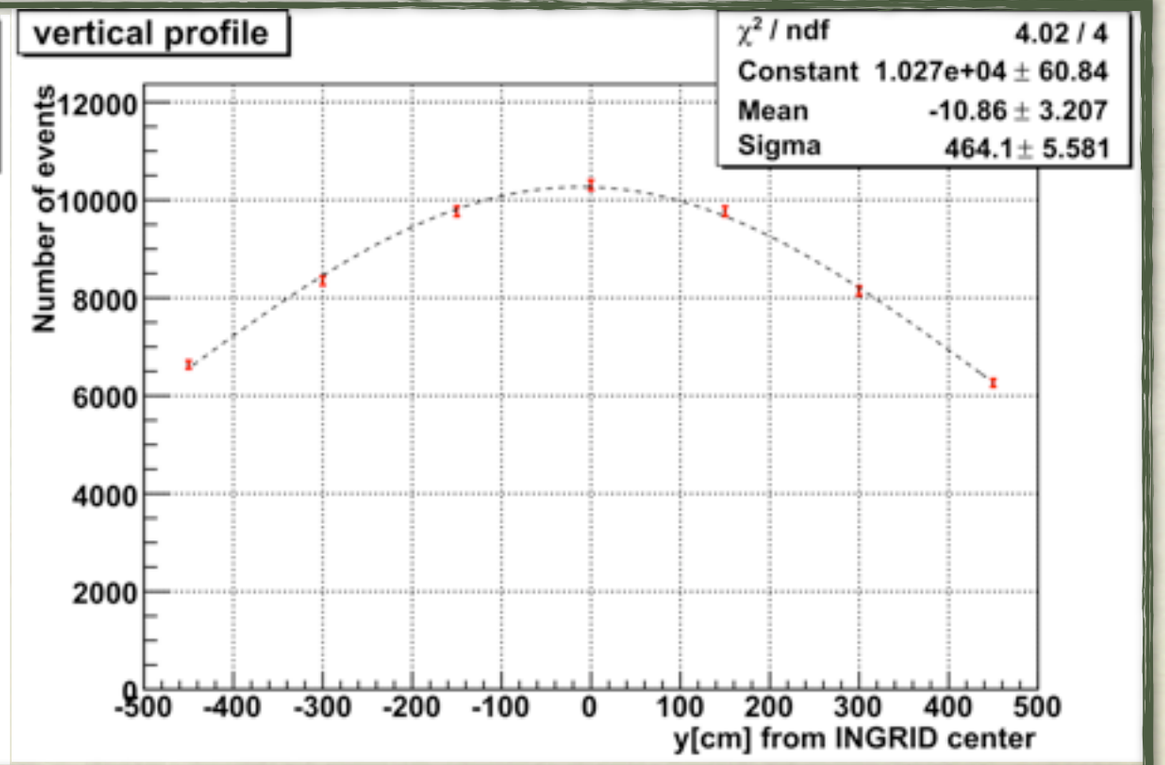


# INGRID: Timing distributions and profile

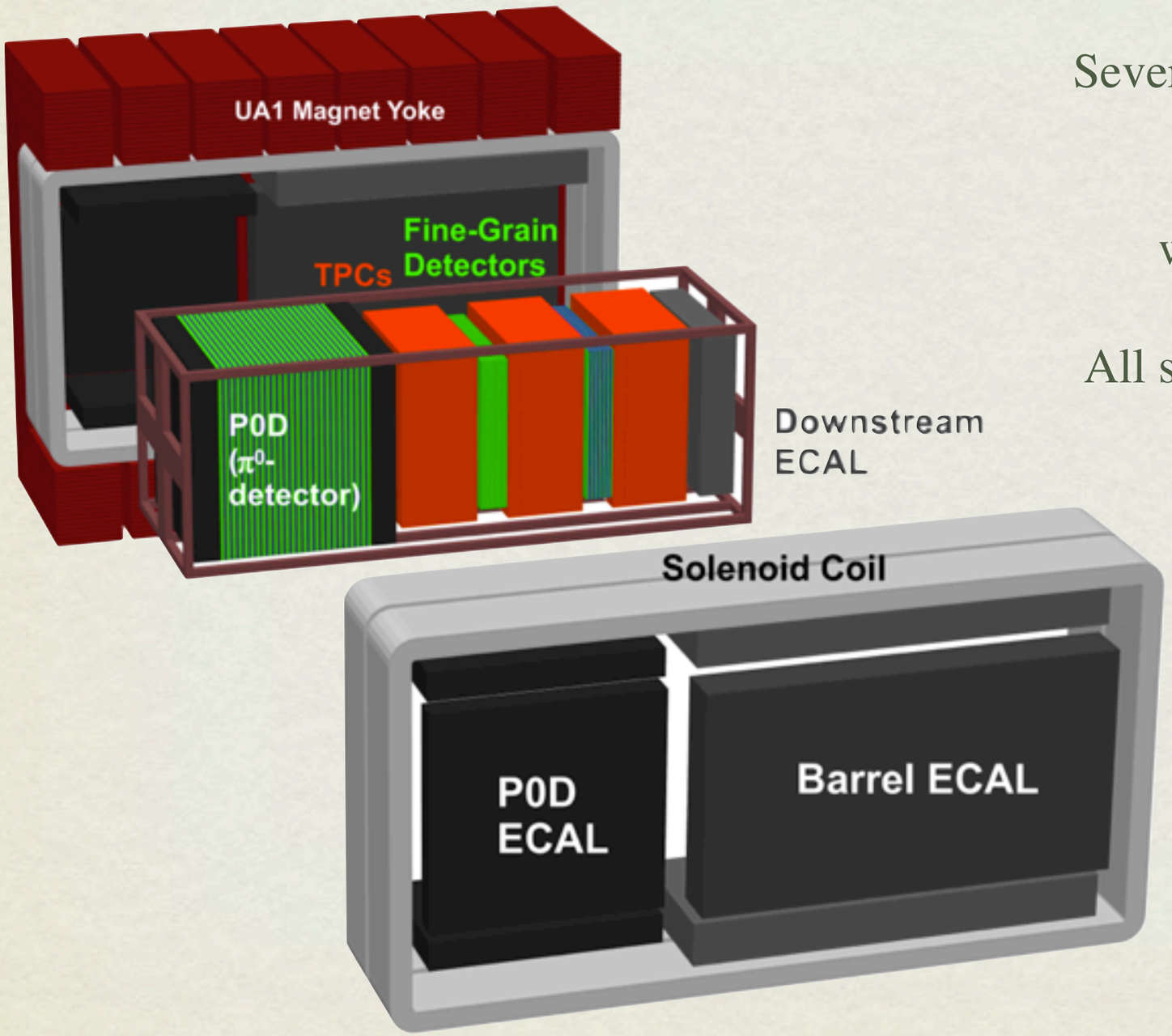


# ND280 off-axis detector




Inside a 0.2 T magnetic field (UA1/NOMAD magnet)

Several fine grained detector and tracker

Would be impossible to use water Cherenkov because of pile-up

All sub-detectors were installed in 2009 and ready for 2010, apart from the barrel ECAL

**Purpose**

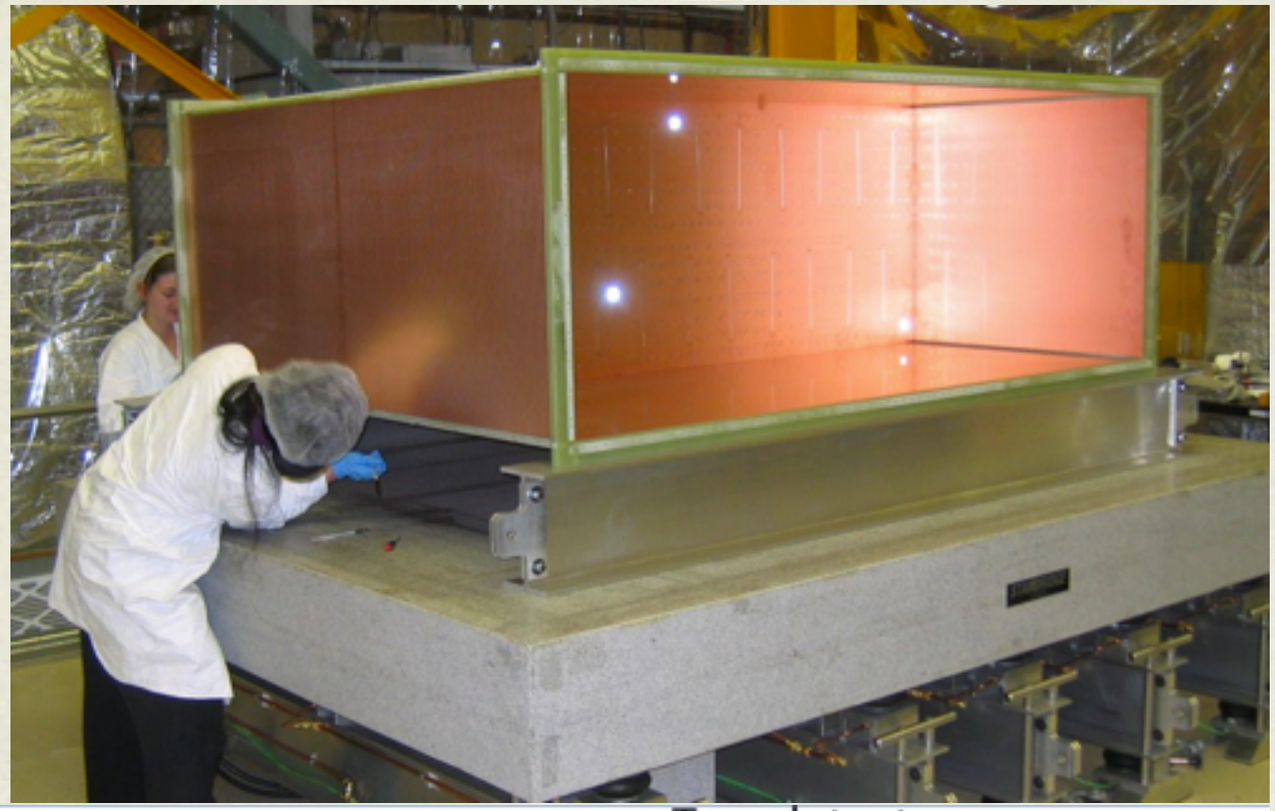
CC $\nu_\mu$ events (normalization, disappearance)

CC $\nu_e$ events

$\pi^0$ events

Backgrounds to $\nu_\mu \rightarrow \nu_e$ search

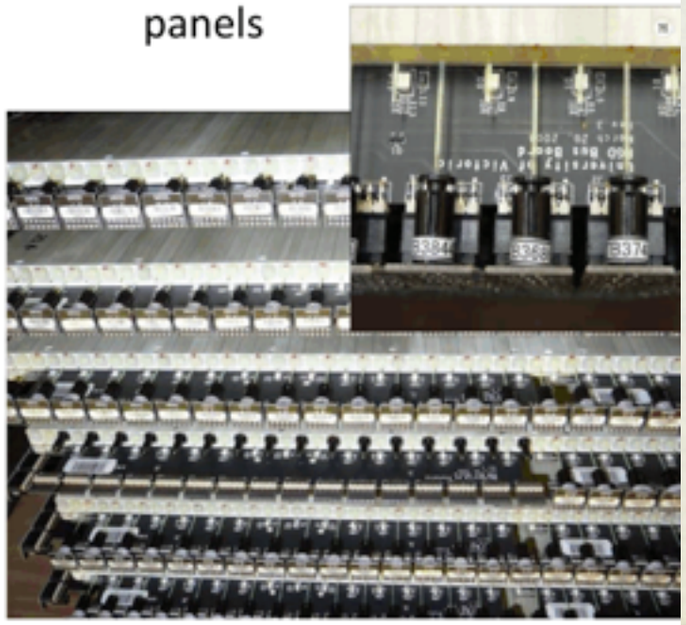
# Tracker: TPC + FGD



**<u>3 Time Projection Chambers (TPC)</u>**

1.8 x 2 x 0.70 $m^3$ sensitive area
World's Largest TPC
with micro-pattern read out (MicroMeGas)
~124k channels

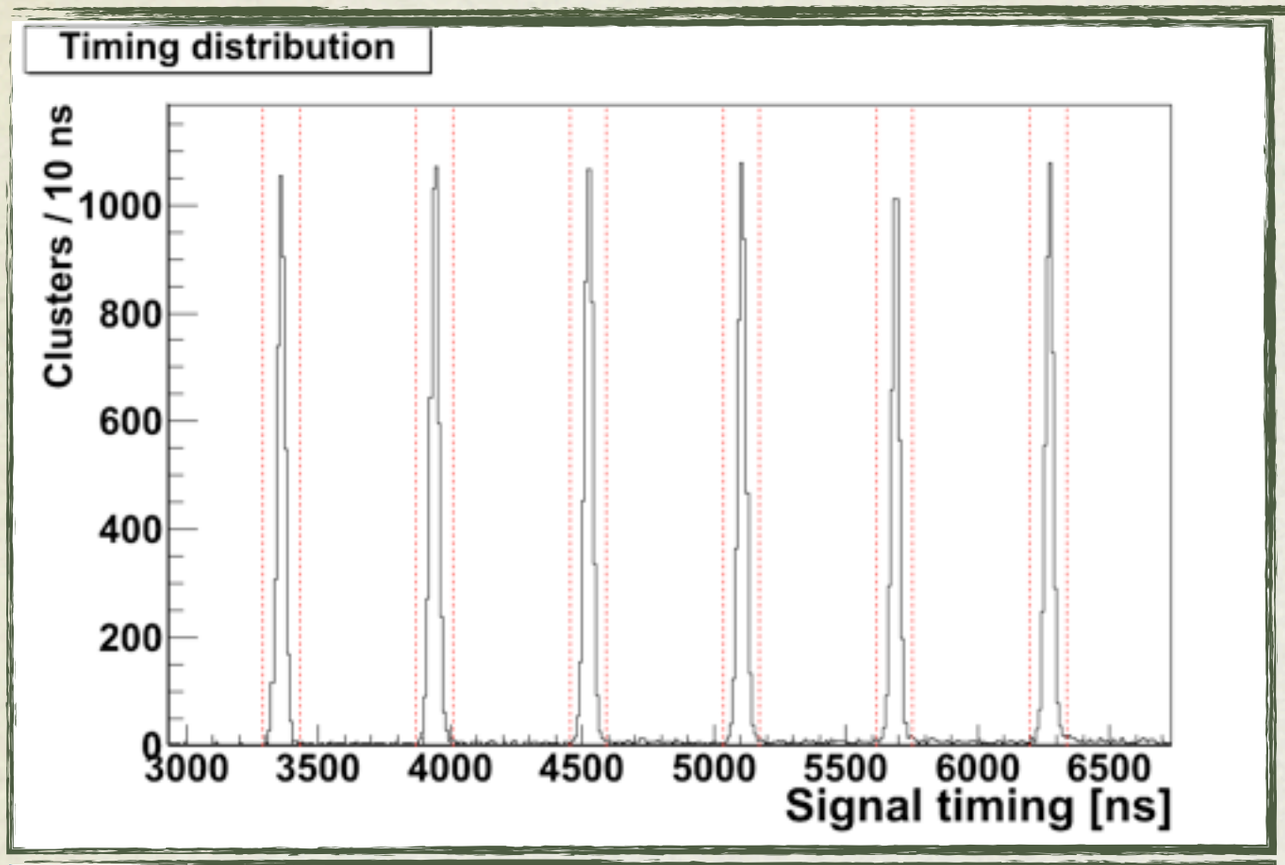
- Two detectors
  - 15 XY layers (192 bars)
  - 7 XY layers + 7 water panels



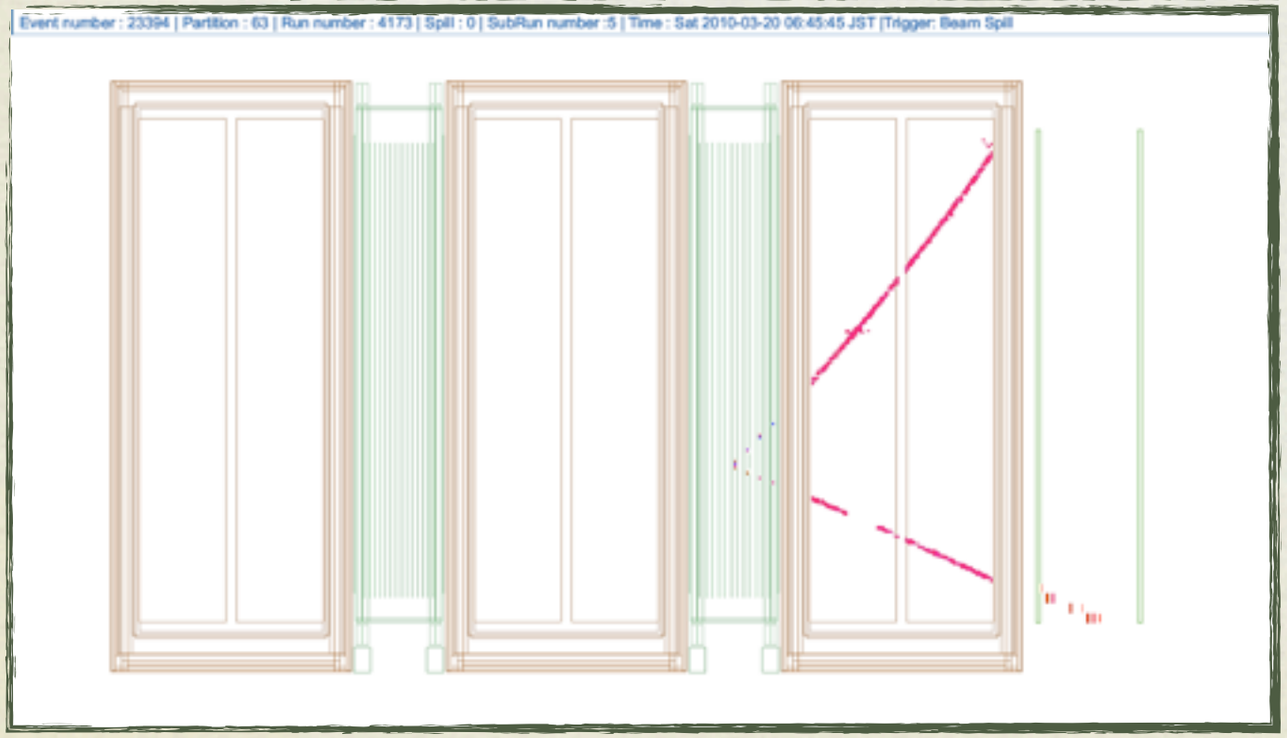
**<u>2 Fine Grained Detectors (FGD)</u>**

2 x1.3 Ton active target
FGD1: plastic only
FGD2: Plastic + water
Light detection by Geiger mode avalanche photodiodes (MPPC)
~ 9500 channels

# Tracker, TPC + FGD: Timing and Event displays

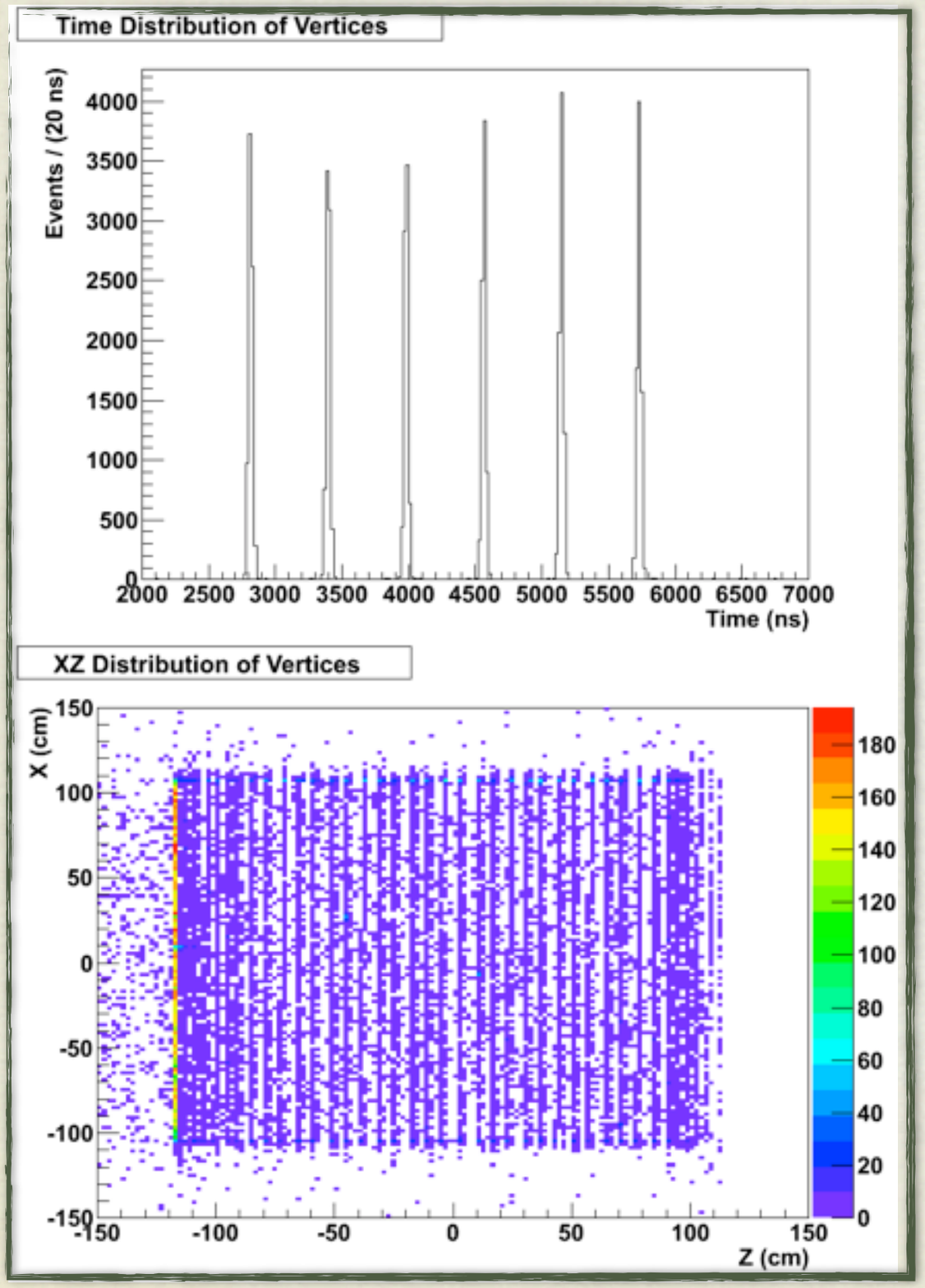



Bunch structure also very well defined in FGD's



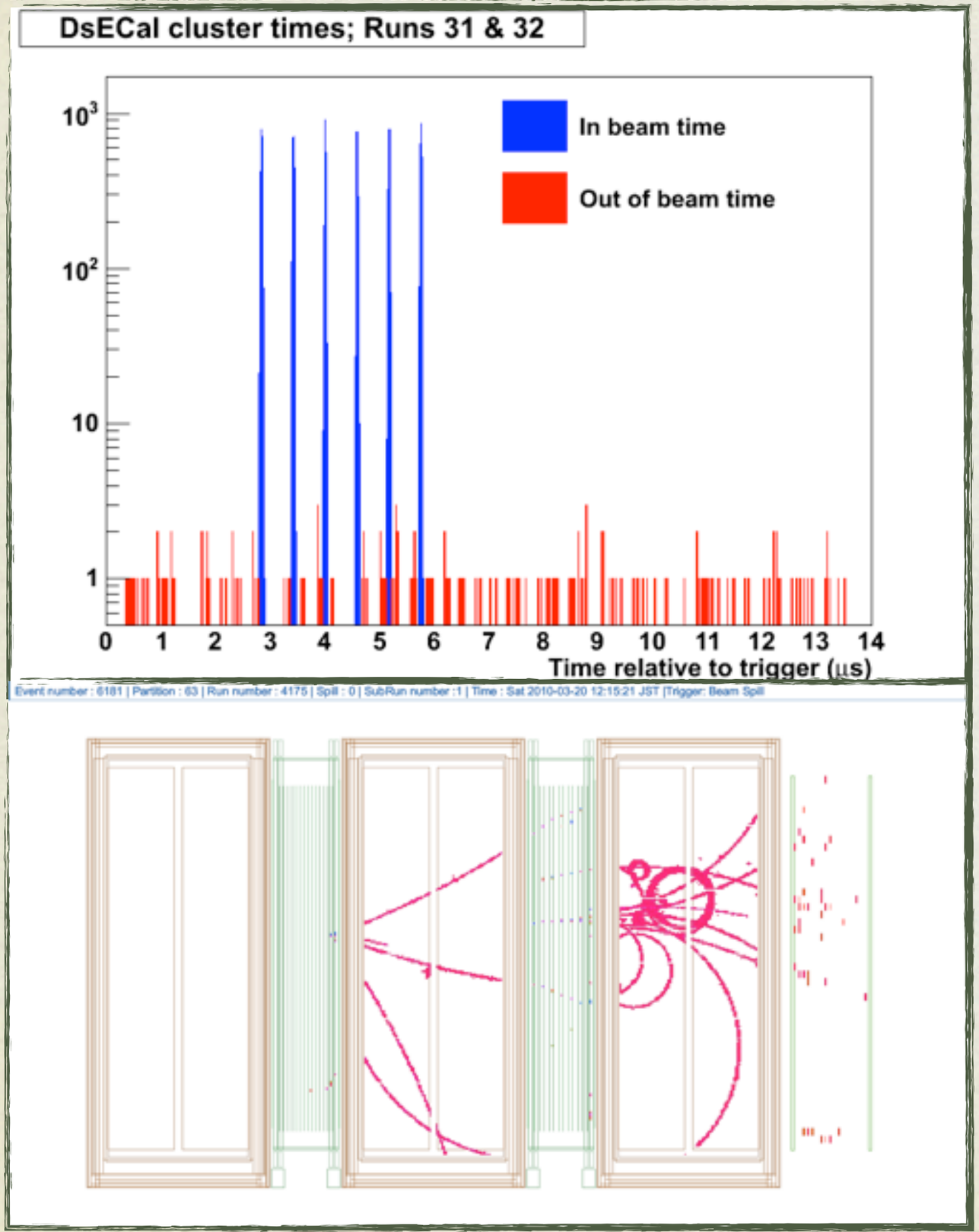

CC interaction in FGD2 with 2 tracks in TPC3

# POD: $\pi^0$ detector -- Timing and vertex distributions




One of 4 supermodules of the P0D

# DsECAL: Downstream Electromagnetic calorimeter





Timing distributions of DsECAL clusters

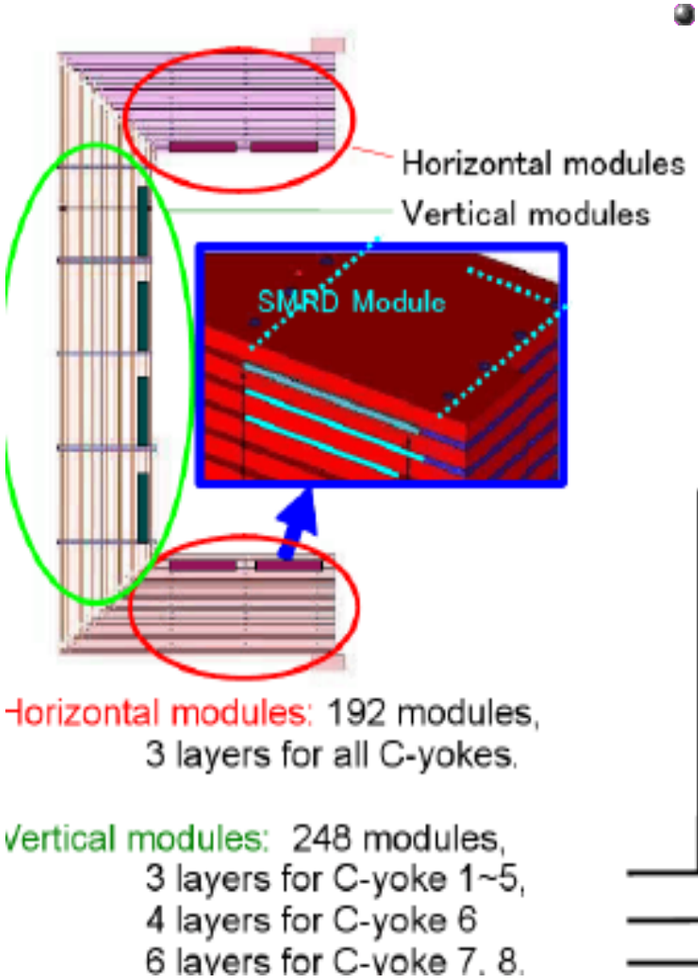


Interaction in FGD1 with shower in FGD2 and DsECAL

# SMRD: Side muon range detector

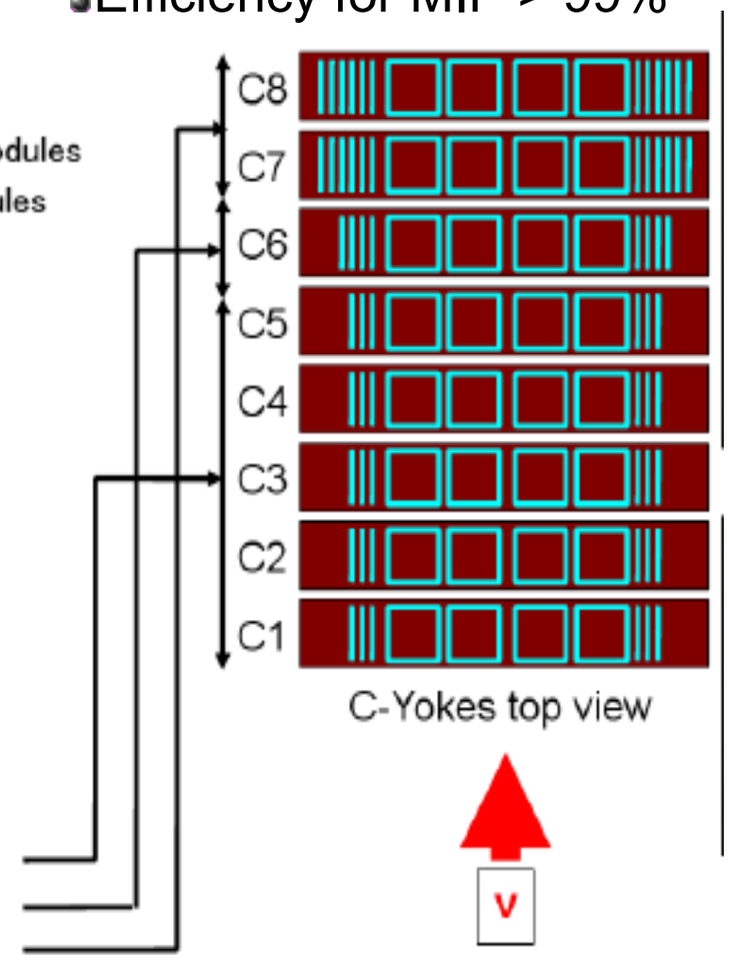
## Side Muon Range Detector:

- Sand muon veto, Cosmic trigger
- Large angle  muon range
- Efficiency for MIP > 99%

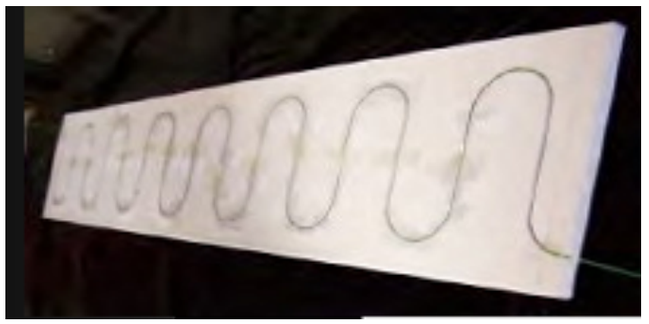



Horizontal modules: 192 modules,
3 layers for all C-yokes.

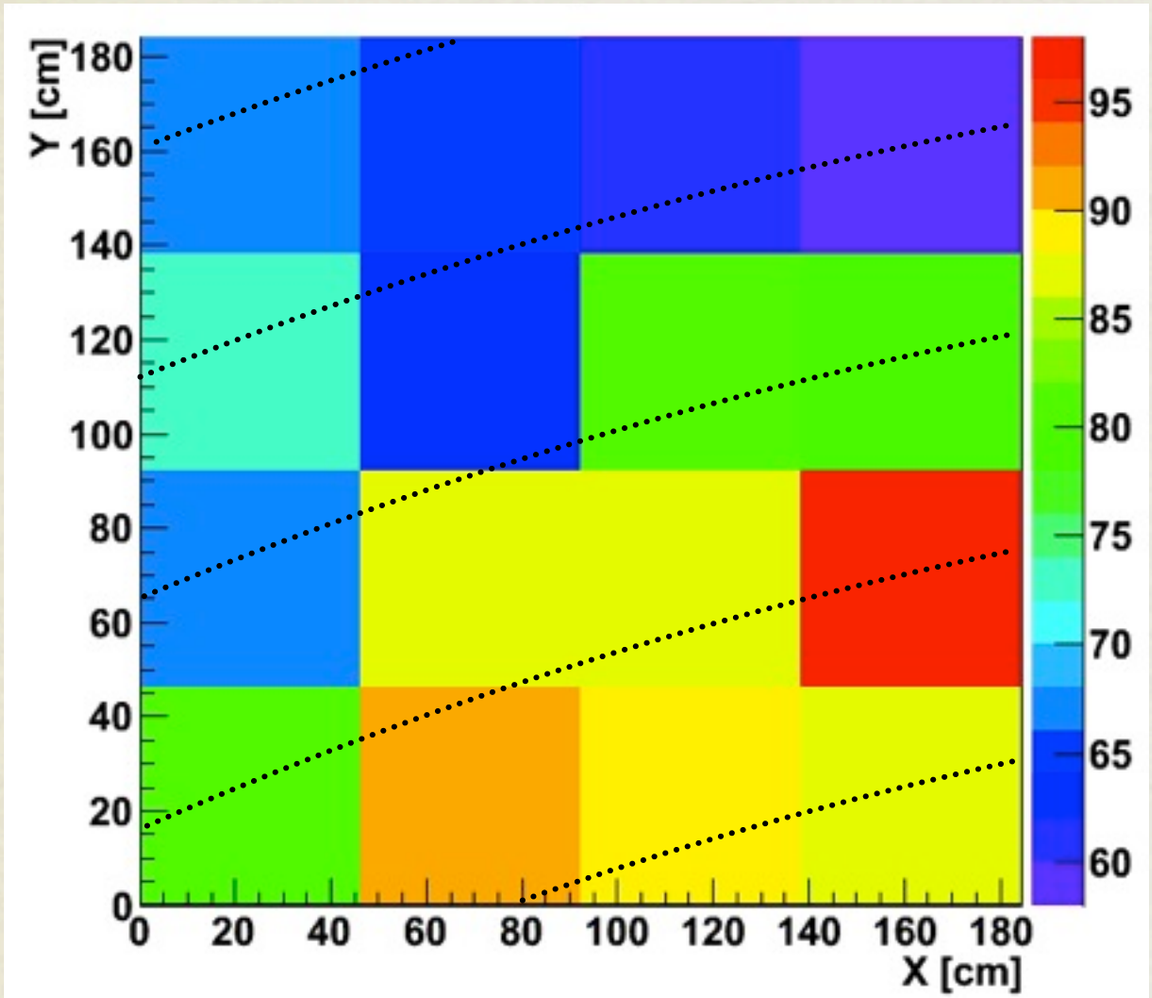
Vertical modules: 248 modules,
3 layers for C-yoke 1~5,
4 layers for C-yoke 6
6 layers for C-yoke 7. 8.




~2k scint. counters (87x17x0.7 cm3)

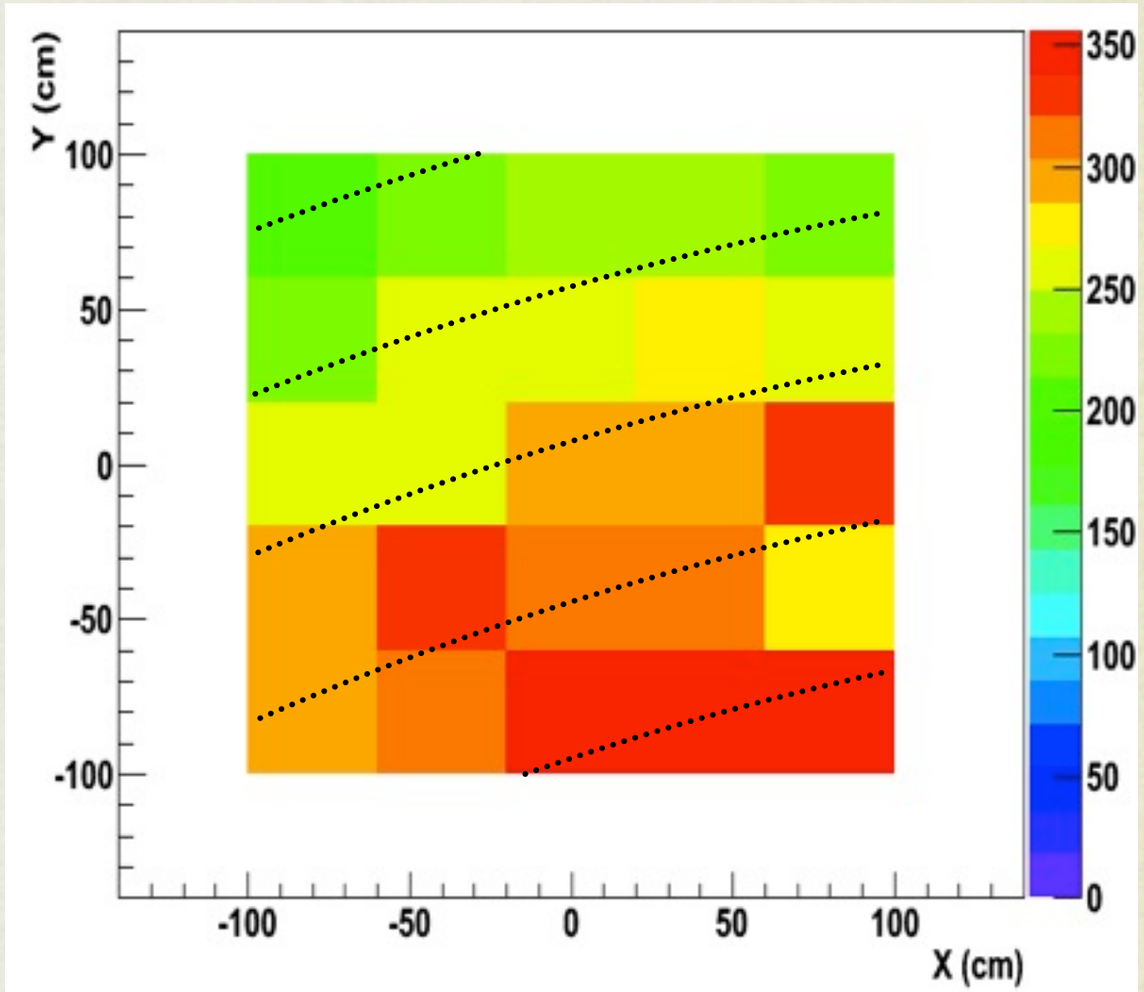


# The off-axis detector is really off-axis!




◀ FGD

POD ▶

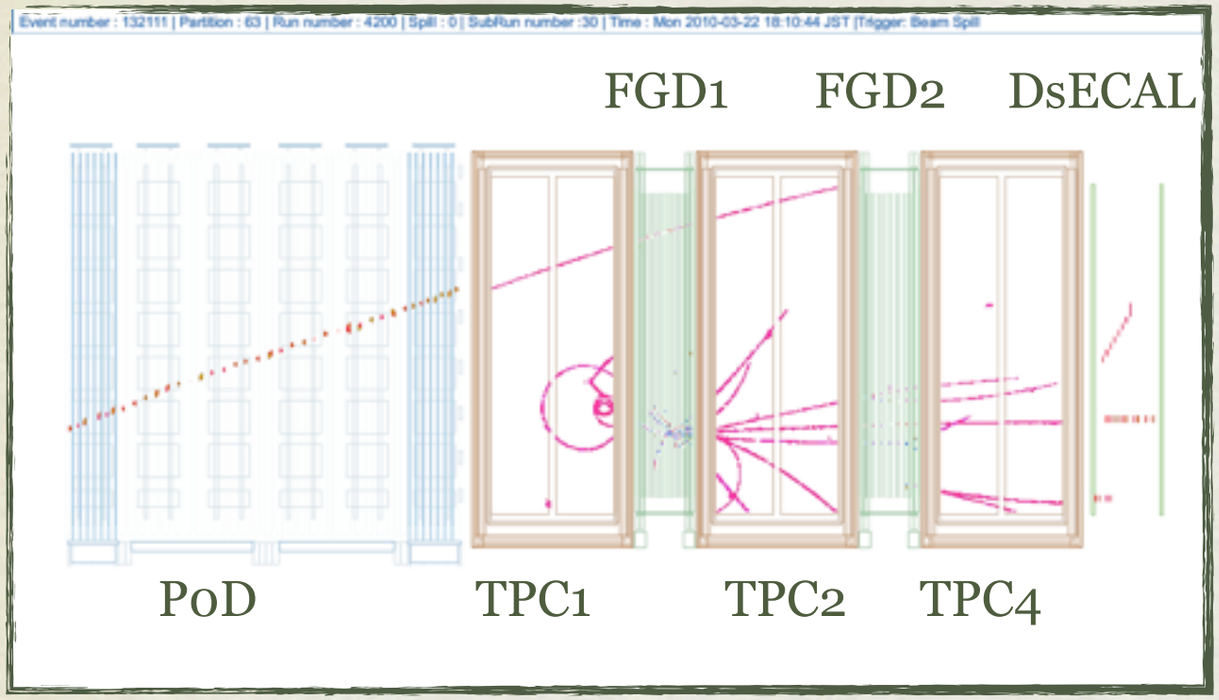


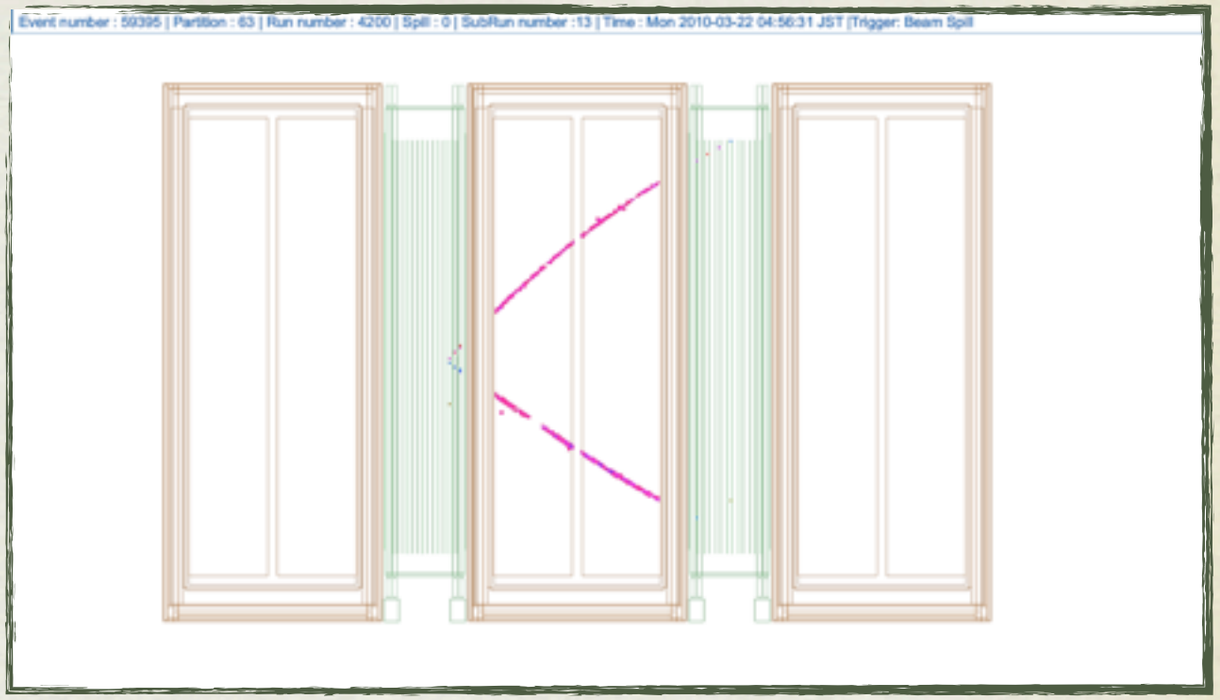

Contained vertices reconstructed in the 2 ‘Fiducial’ detectors.

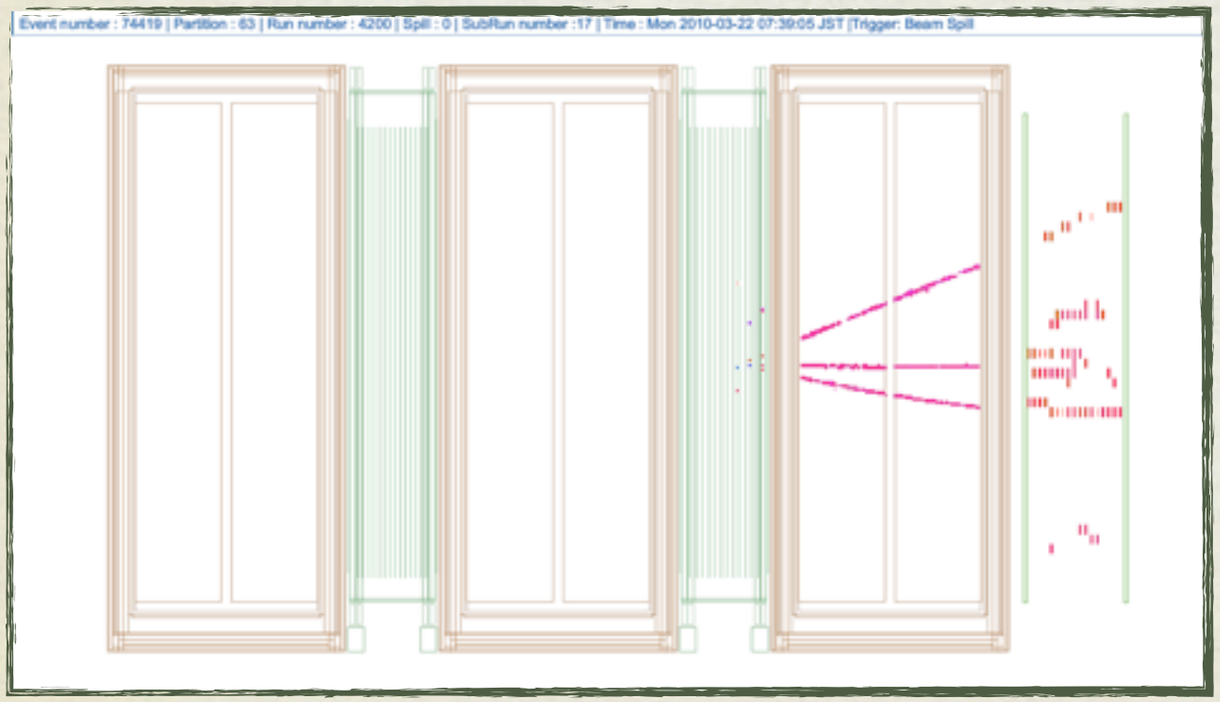
Lines show (approximate) iso-contours of off-axis angle.

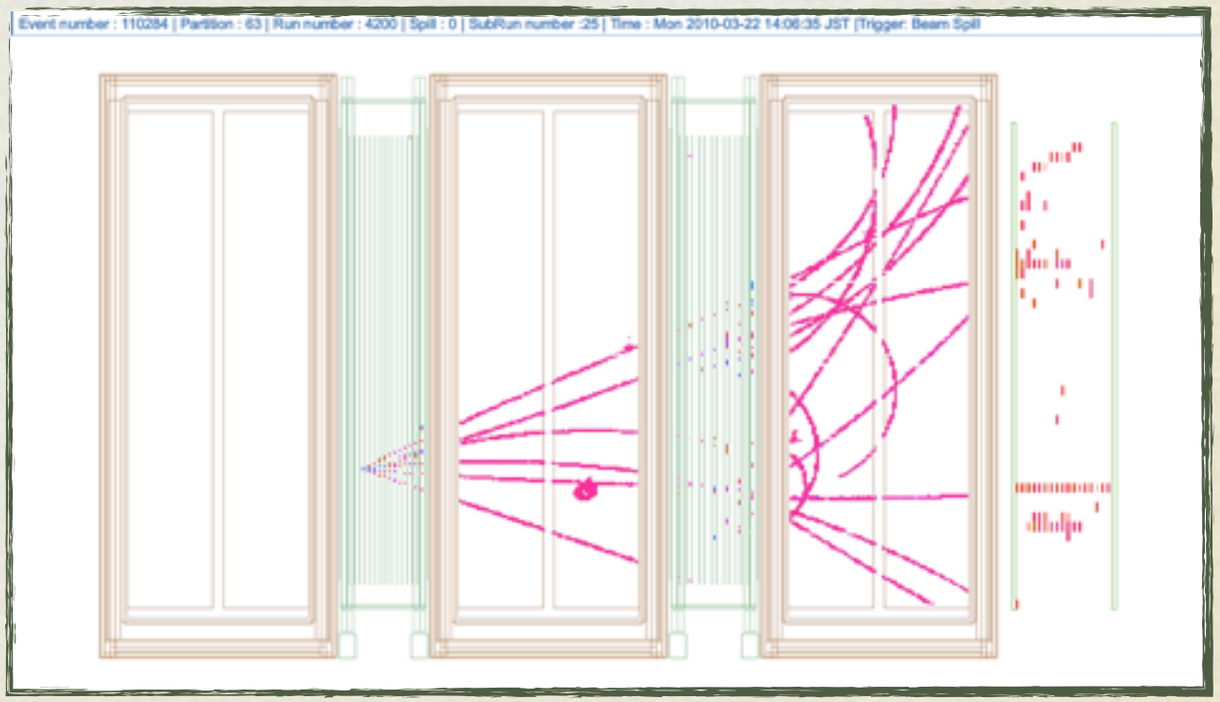
Outer corner is roughly 20% further off-axis than inner corner.

# Overview of events in the off-axis ND280







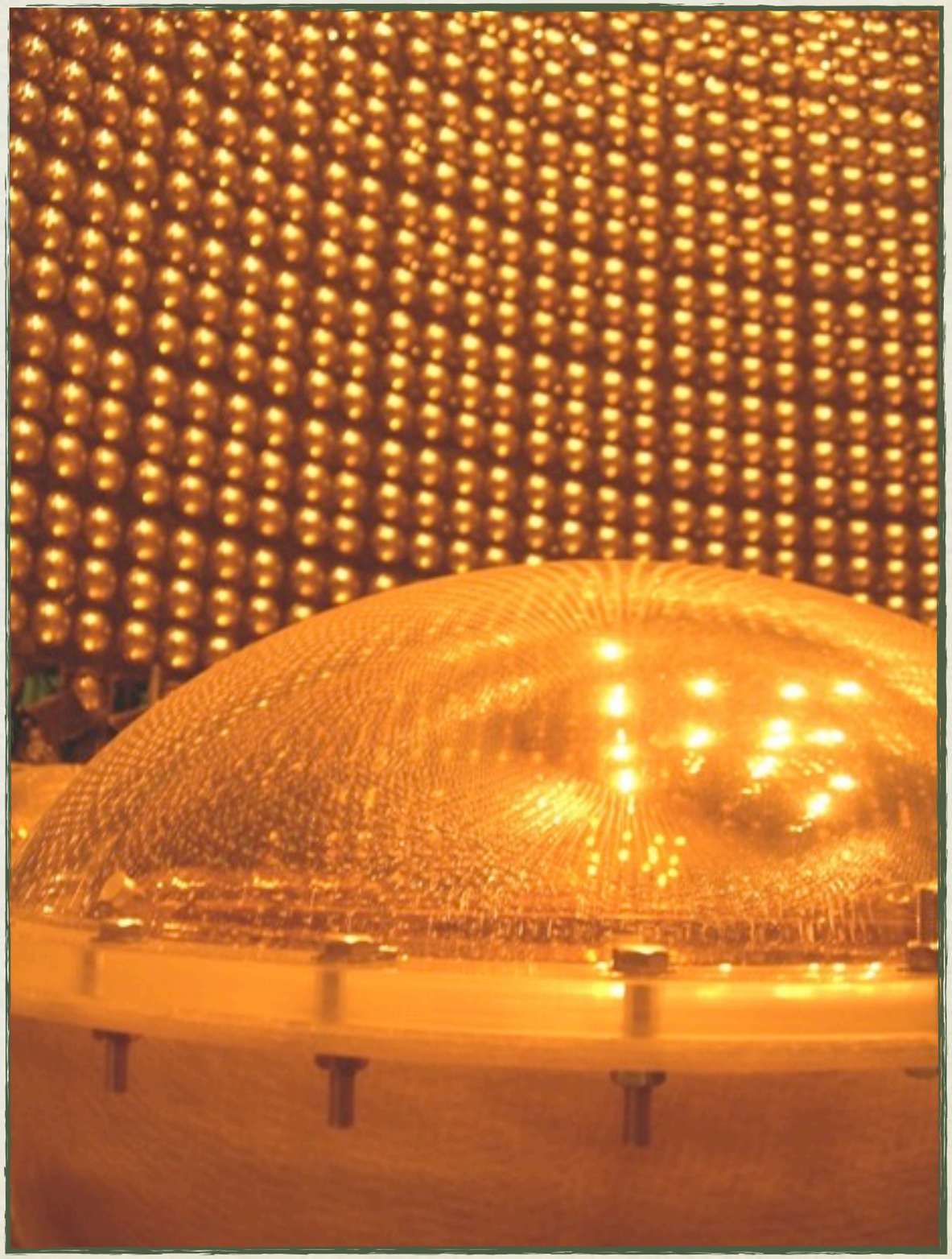
# Super-Kamiokande overview

Stability of the detector

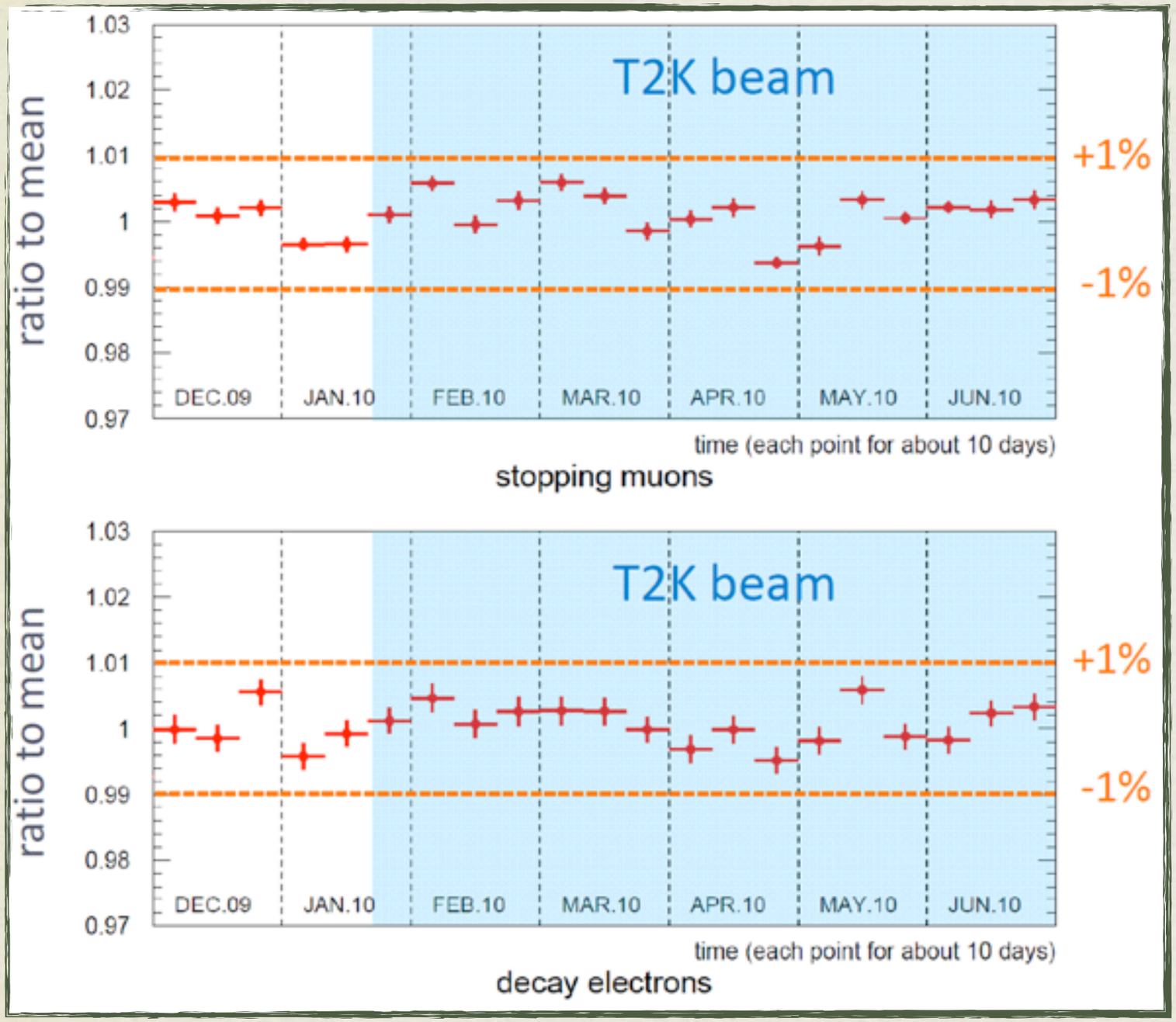
Event rate

Vertex distributions

Event displays



# Energy scale stability




RMS/MEAN
T2K period : 0.31%
(SK-IV all : 0.39%)

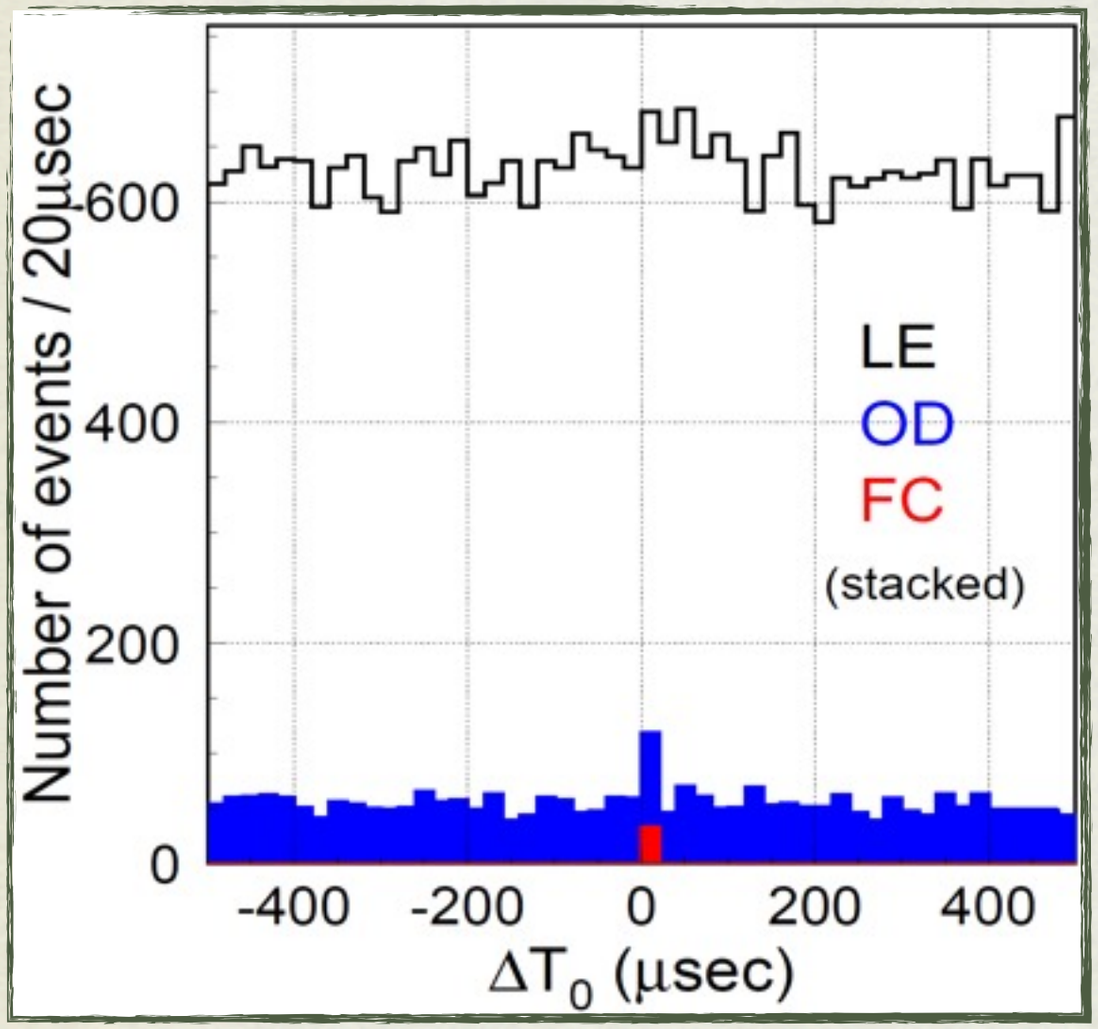
RMS/MEAN
T2K period : 0.28%
(SK-IV all : 0.45%)

Very stable energy scale during T2K running period

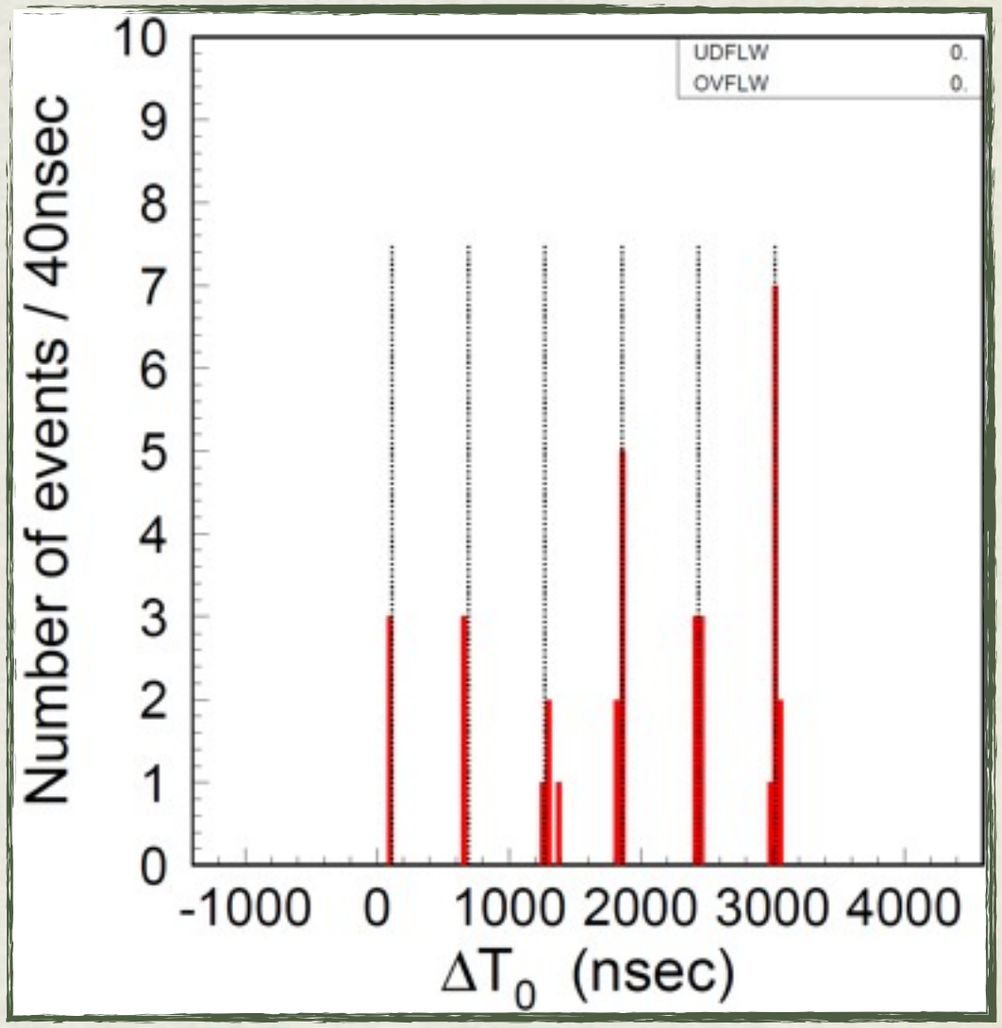
# Event rates and timing

$\Delta T_0$ : relative event time to the spill time

$\Delta T_0$ : -500 ~ +500 μsec




Fitted 581 ns-interval bunch position




Out-of-time OD/LE rate is flat.
No out-of-time FC events.

GPS system is working correctly

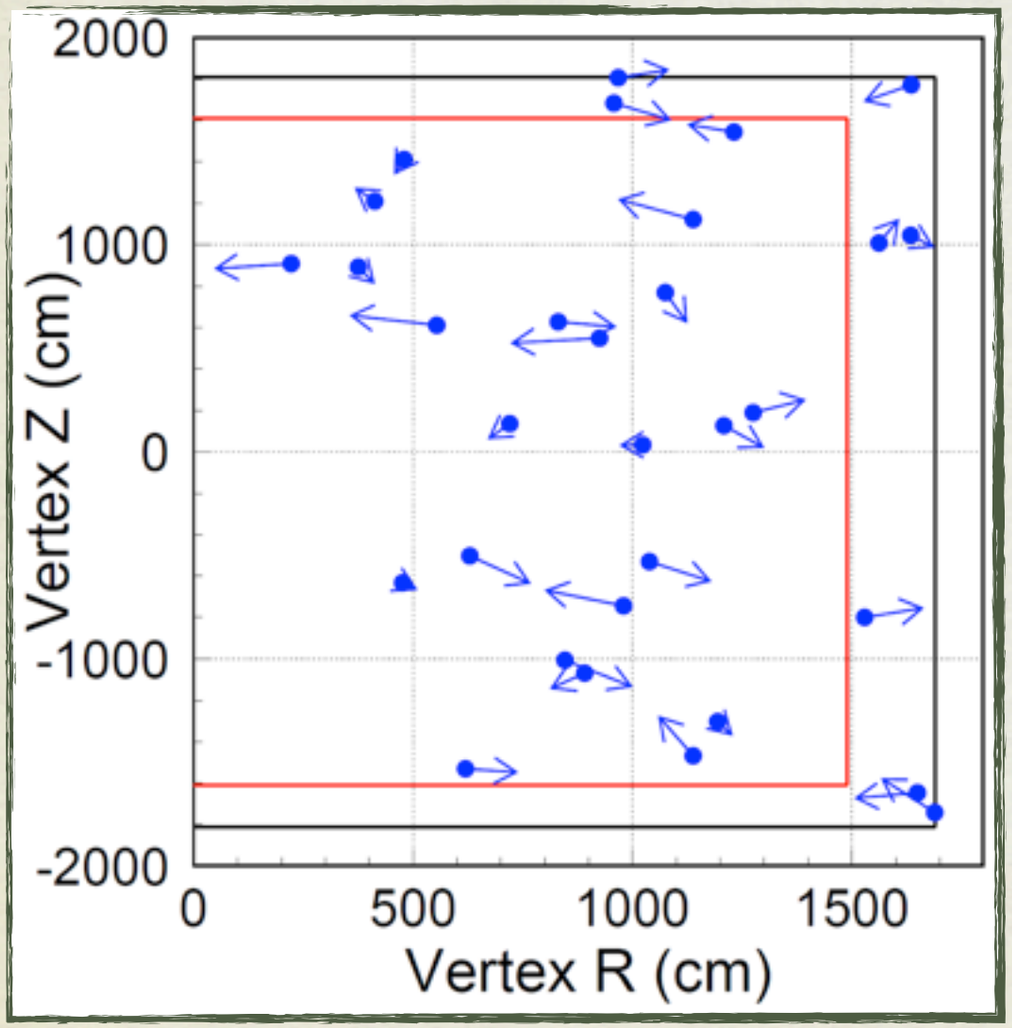
# Super-Kamiokande status - Selection cuts

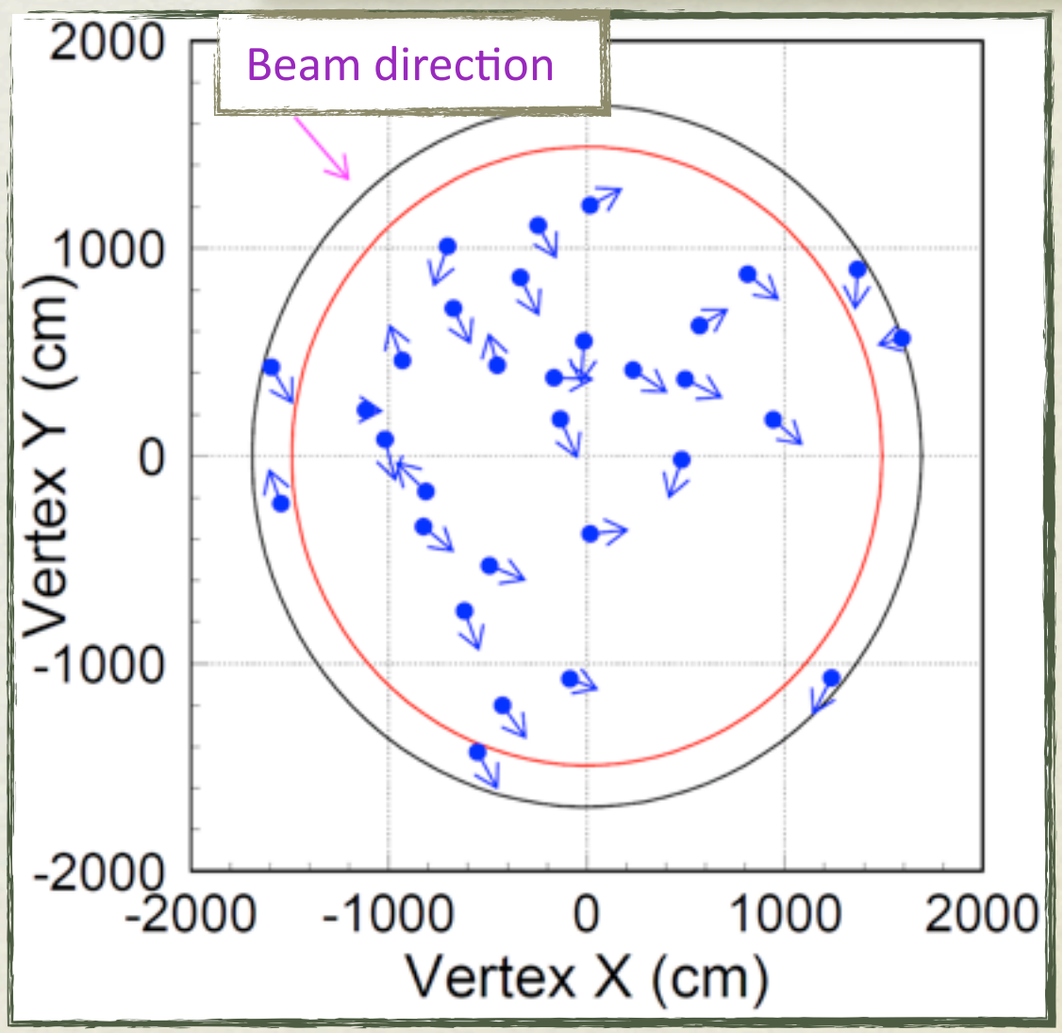
| For $\nu_\mu$ disappearance analysis | For $\nu_e$ appearance search |
|---|---|
| **Timing coincident w/ beam time (+TOF)** | |
| **Fully contained (No OD activity)** | |
| **Vertex in fiducial volume (Vertex >2m from wall)** | |
| $E_{vis}$ > 30MeV | $E_{vis}$ > 100MeV |
| **nº of rings =1** | |
| **μ-like ring** | **e-like ring** |
| | **No decay electron** |
| | **Inv. mass w/ forced-found 2nd ring < 105MeV** |
| | $E_\nu^{rec}$ < 1250MeV |

# Event rates and vertex distributions

| | # of events |
|---|---|
| Fully-Contained | 33 |
| + FV cuts (FV)<br>+Visible energy >30 MeV (FVFC) | 23 |

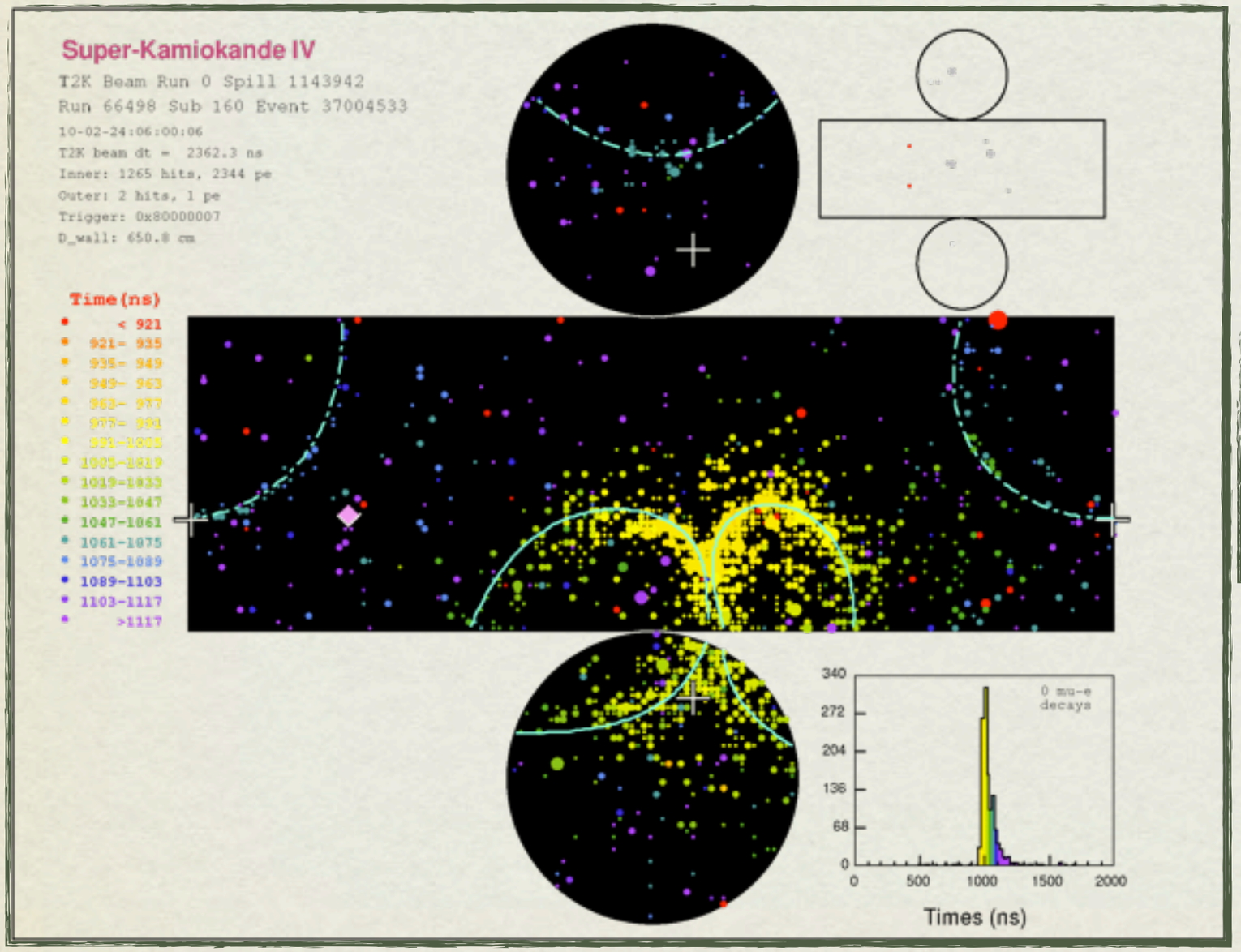
Points :
Reconstructed event vertex
Arrow :
1st-ring direction




Vertices are evenly distributed throughout the detector

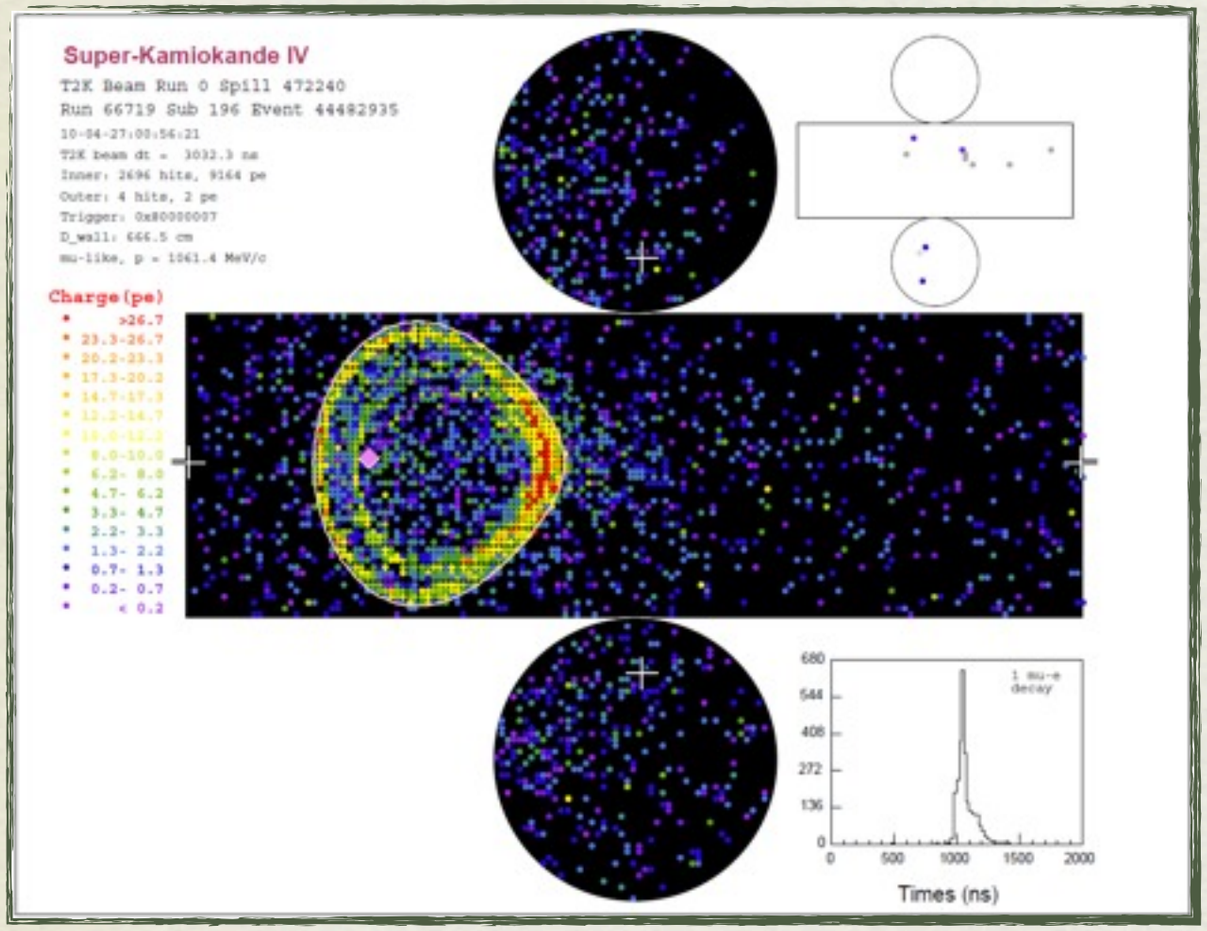
# First look - in far detector (1st event at SK)

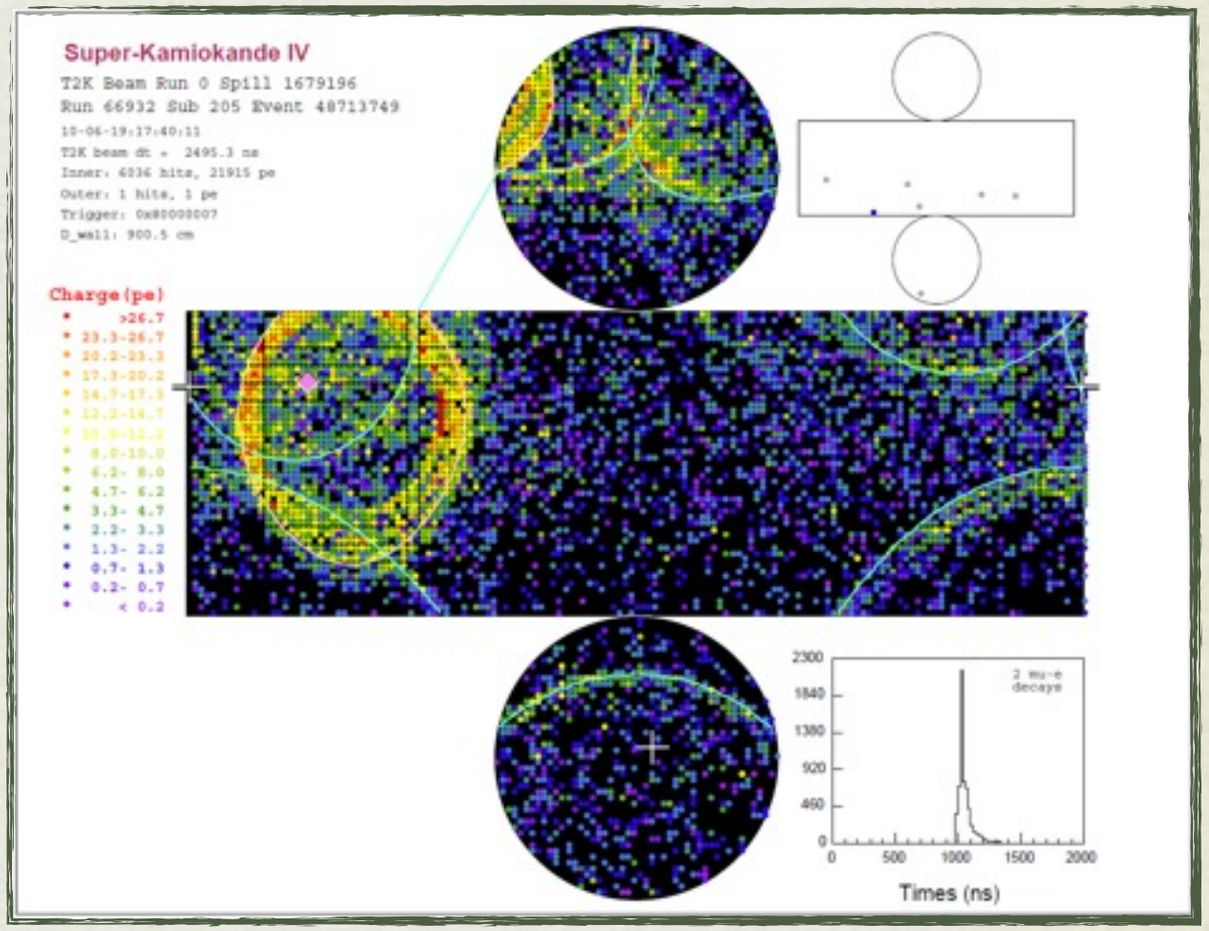



February 24th 2010!

[ 1st ring + 2nd ring ]
Invariant mass: 133.8 MeV/c²
(close to $\pi^0$ mass)
Momentum: 148.3 MeV/c

# Two more mu-like events




Single ring mu-like

$P_\mu$= 1061 MeV/c -- 1 decay electron

April 27th, 2010

Multi ring mu-like

$P_\mu$= 1438 MeV/c -- 2 decay electrons

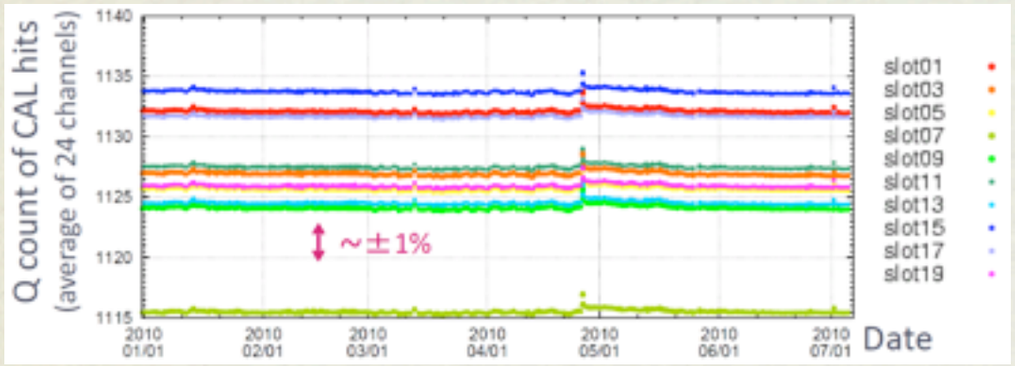
June 19th, 2010

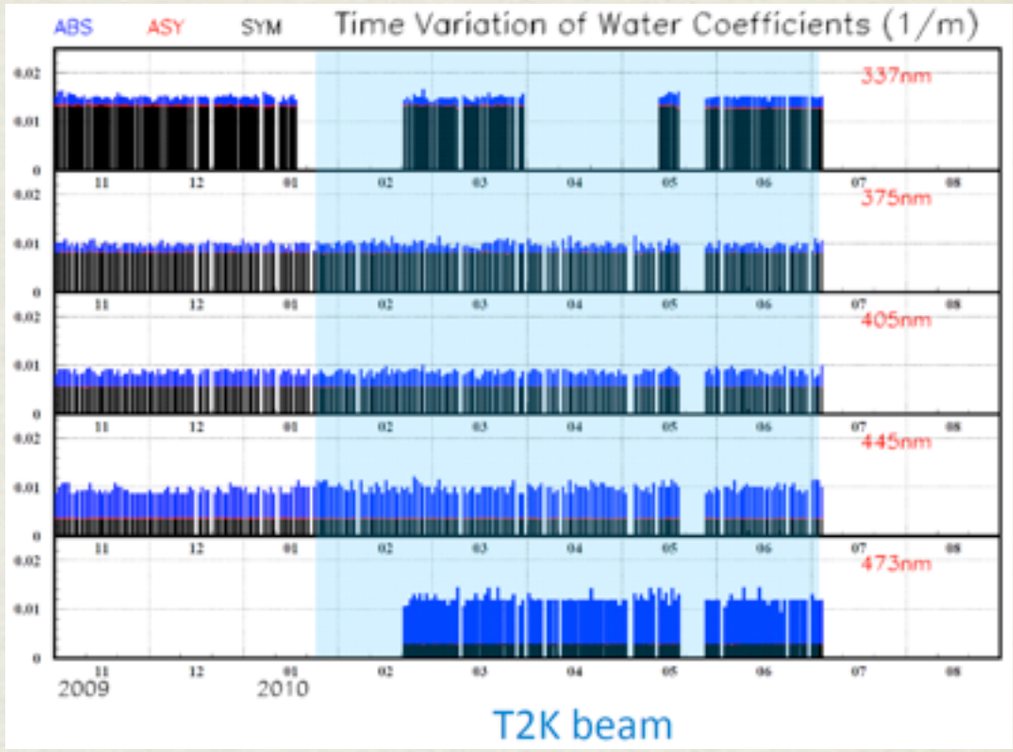
# Conclusions

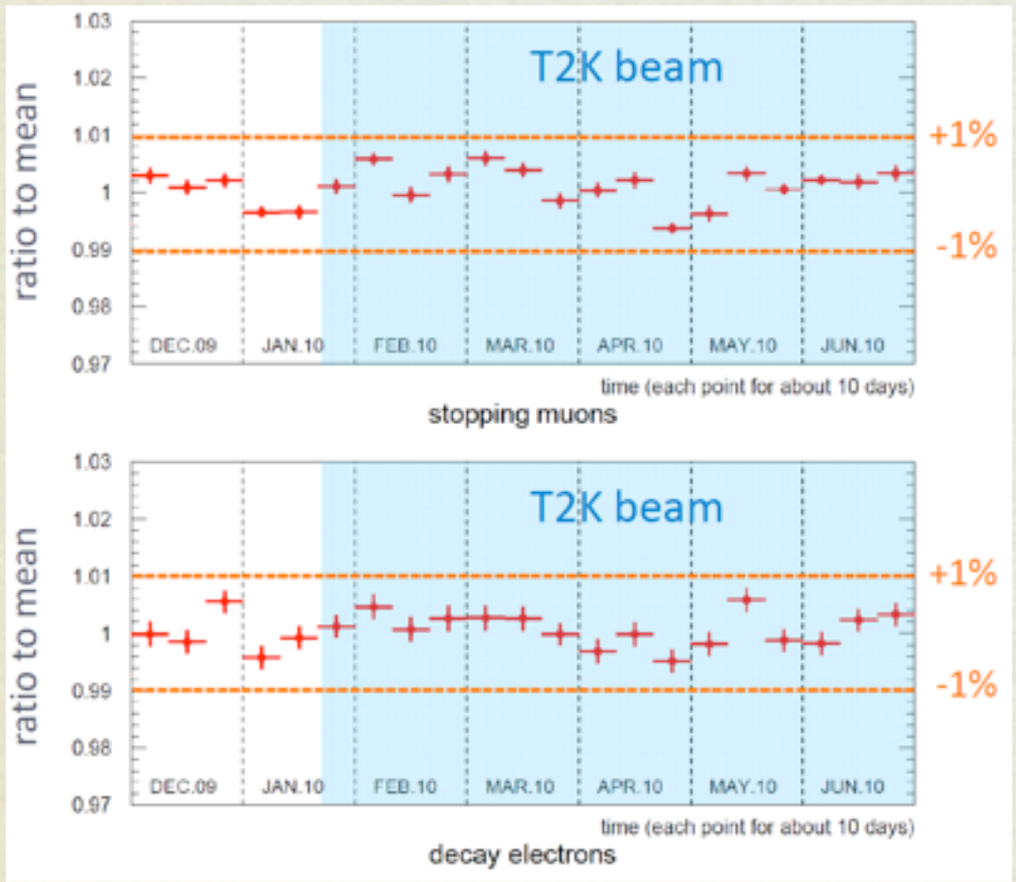
- T2K experiment is now fully operational and data taking
- Superb detector performance both at ND280 and SK
- Proton intensity increasing steadily
- First data taking period in 2010 accumulated 3.3 $10^{19}$ @ 30 GeV p.o.t.
- Preparing first physics result for end 2010
  - Collaboration meeting is happening this week = Results should be out soon!

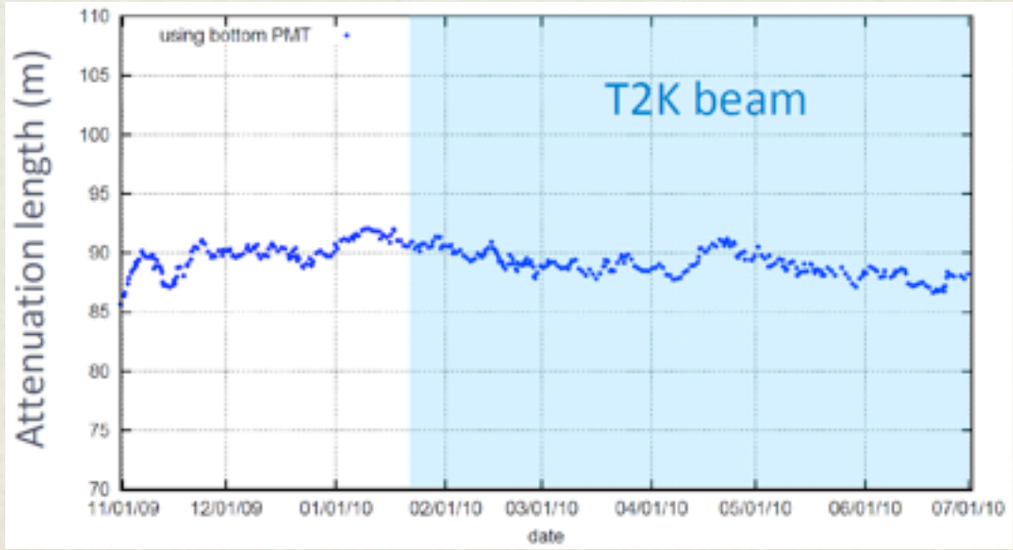
# Backups

# SK stability



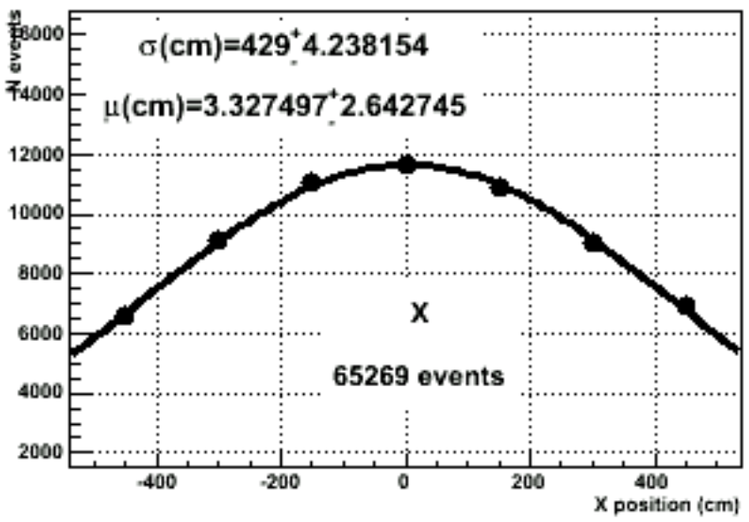



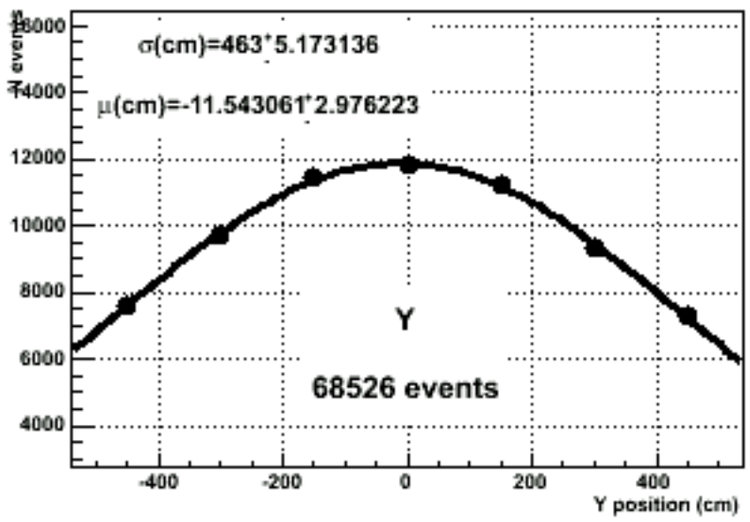
$$P(\nu_\mu \to \nu_\mu) \approx 1.0 - \left( \sin^2(2\theta_{23}) \cos^2(\theta_{31}) + \sin^2(2\theta_{31}) \cos^2(\theta_{23}) \right) \sin^2(\frac{\Delta m^2_{23} L}{4E})$$

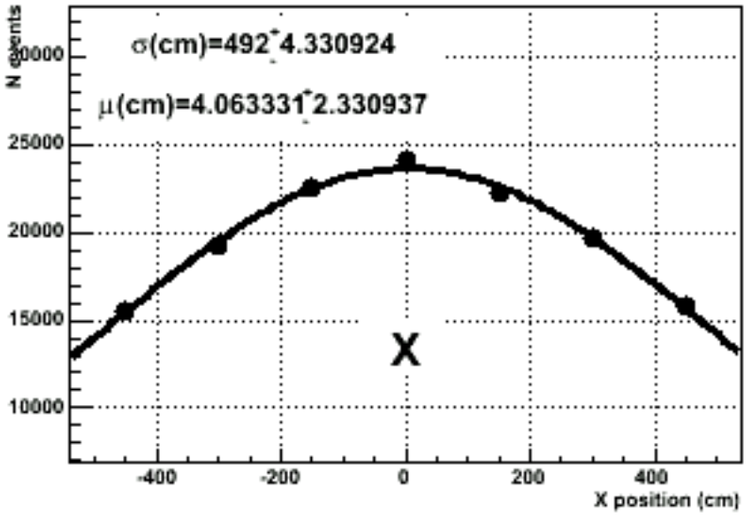
$$P(\nu_\mu \to \nu_\mu) \approx 1.0 - (\sin^2(2\theta_{23})) \sin^2(\frac{\Delta m^2_{23} L}{4E})$$

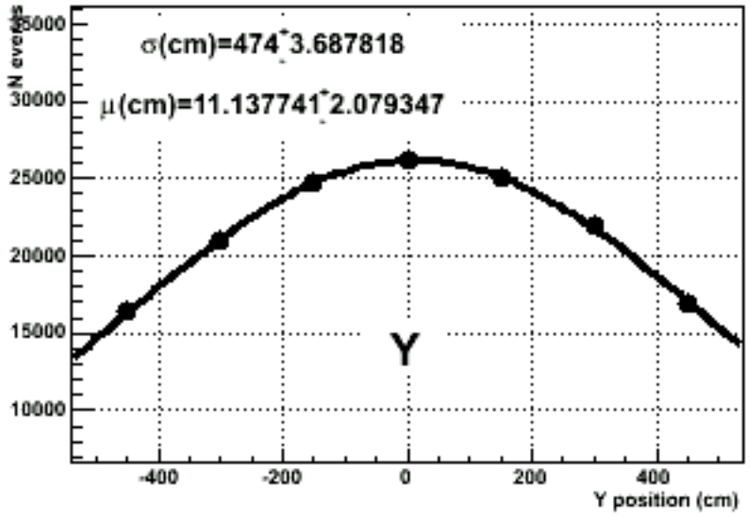
$$P(\nu_\mu \to \nu_e) \approx \left( \sin^2(\theta_{23}) \sin^2(2\theta_{31}) \right) \sin^2(\frac{\Delta m^2_{23} L}{4E})$$

# Horizontal / Vertical for INGRID run 34

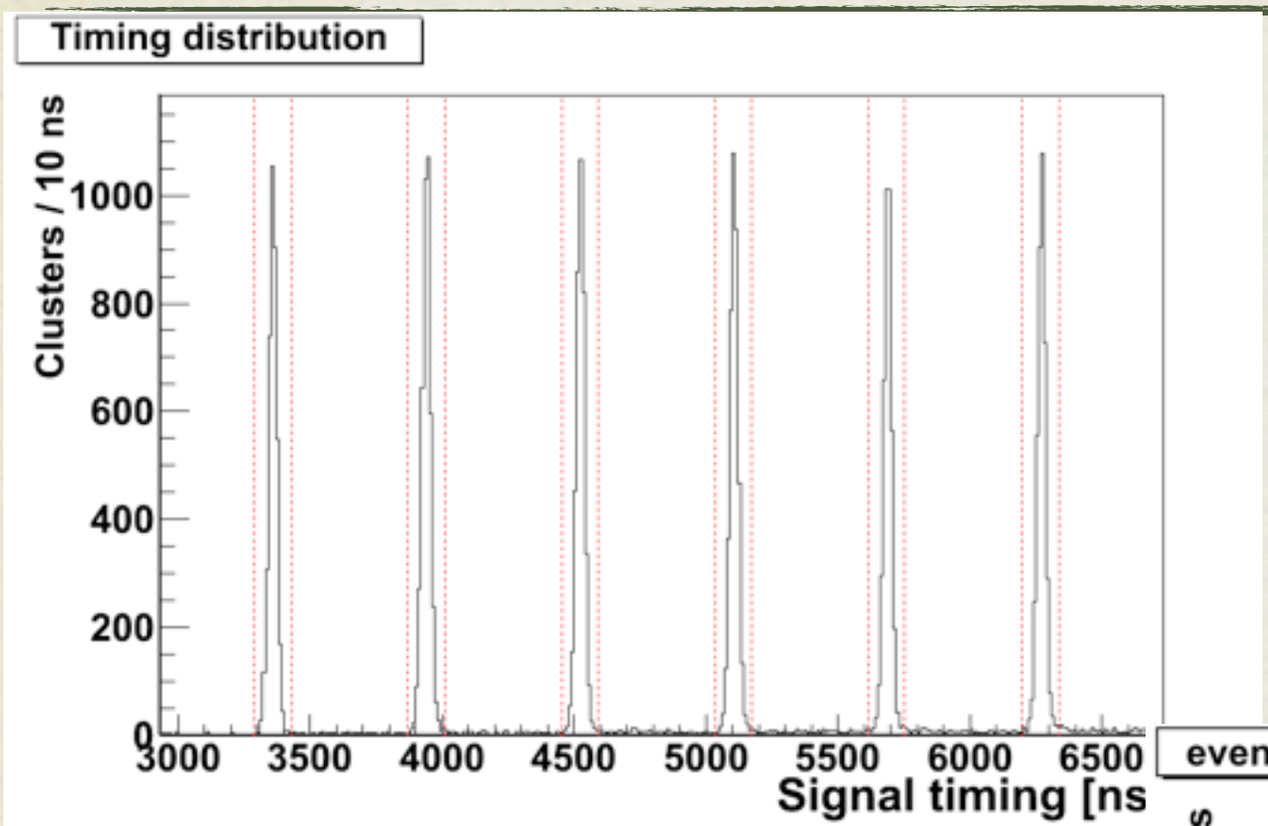


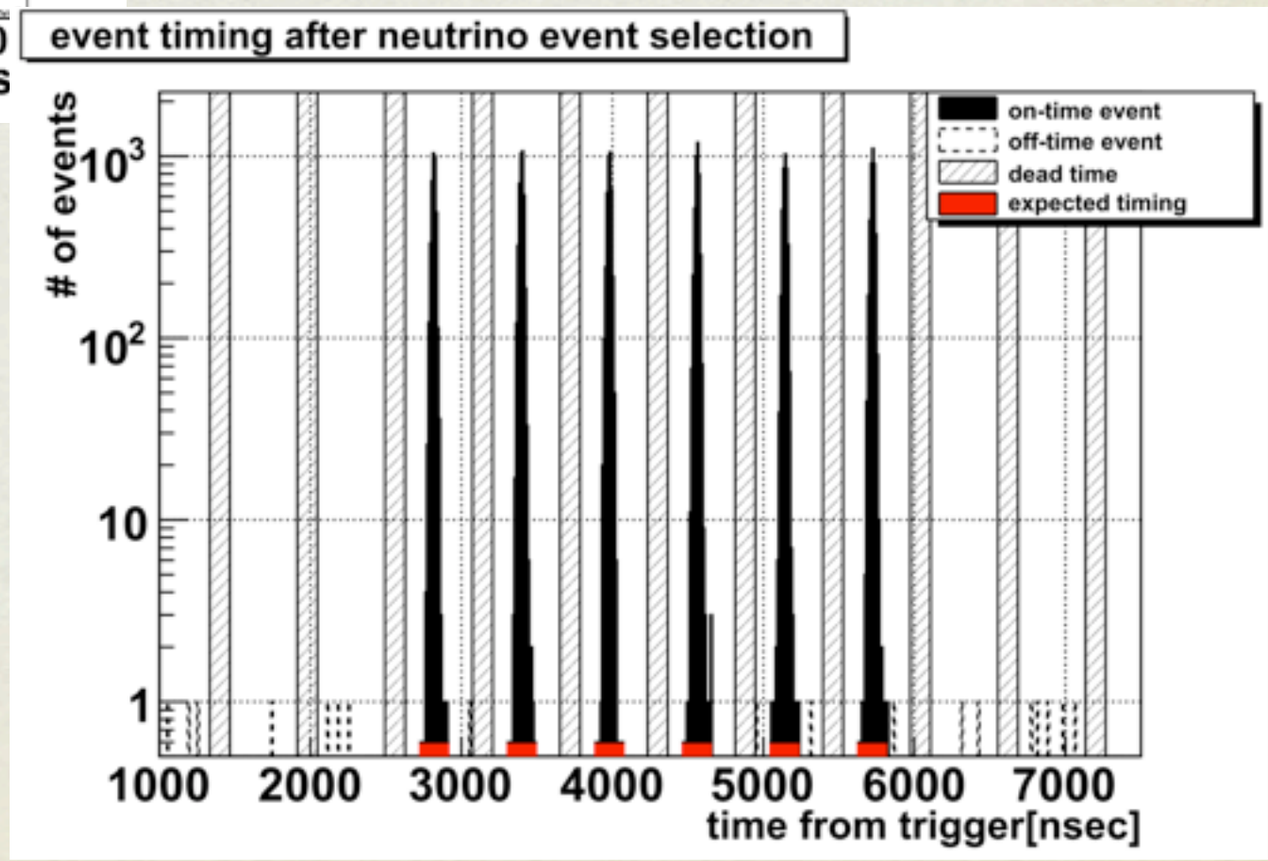



# FGD and INGRID timing



# SMRD