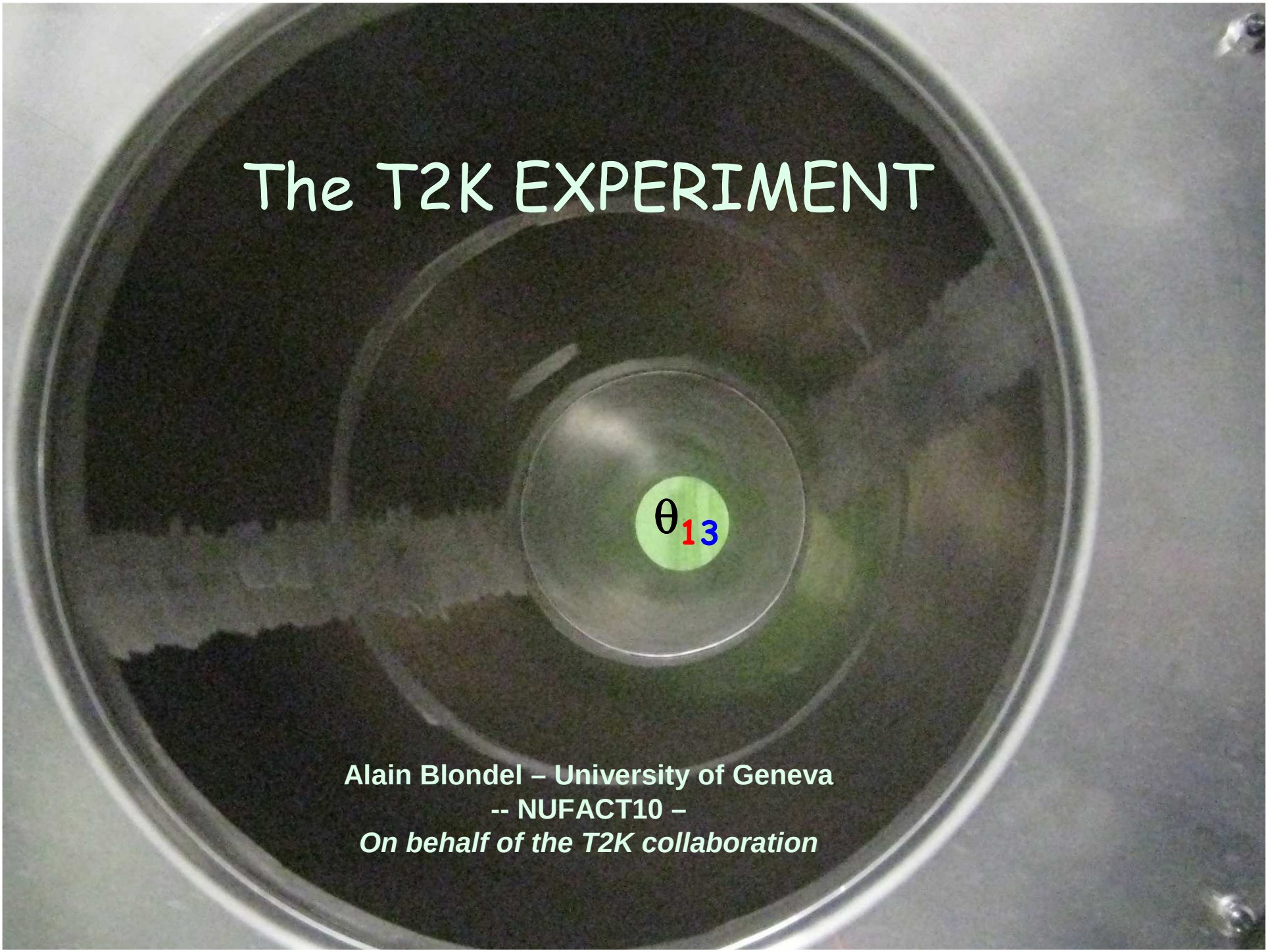
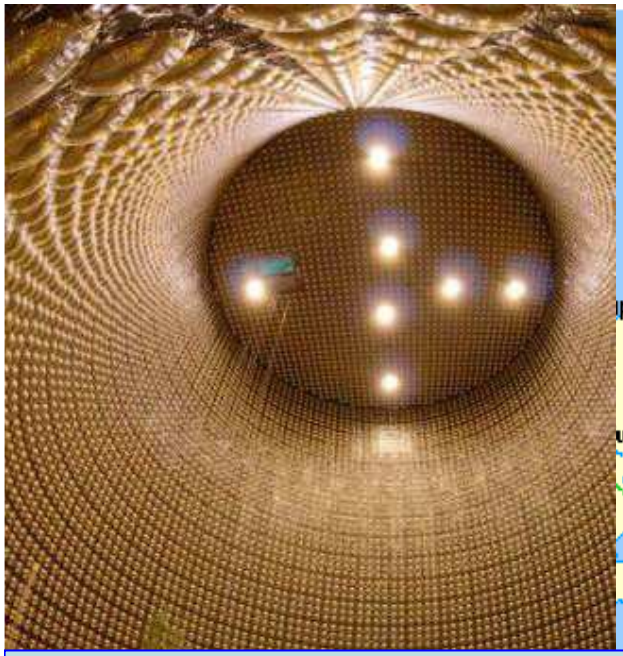


The T2K EXPERIMENT

θ_{13}

Alain Blondel – University of Geneva
-- NUFACT10 –
On behalf of the T2K collaboration

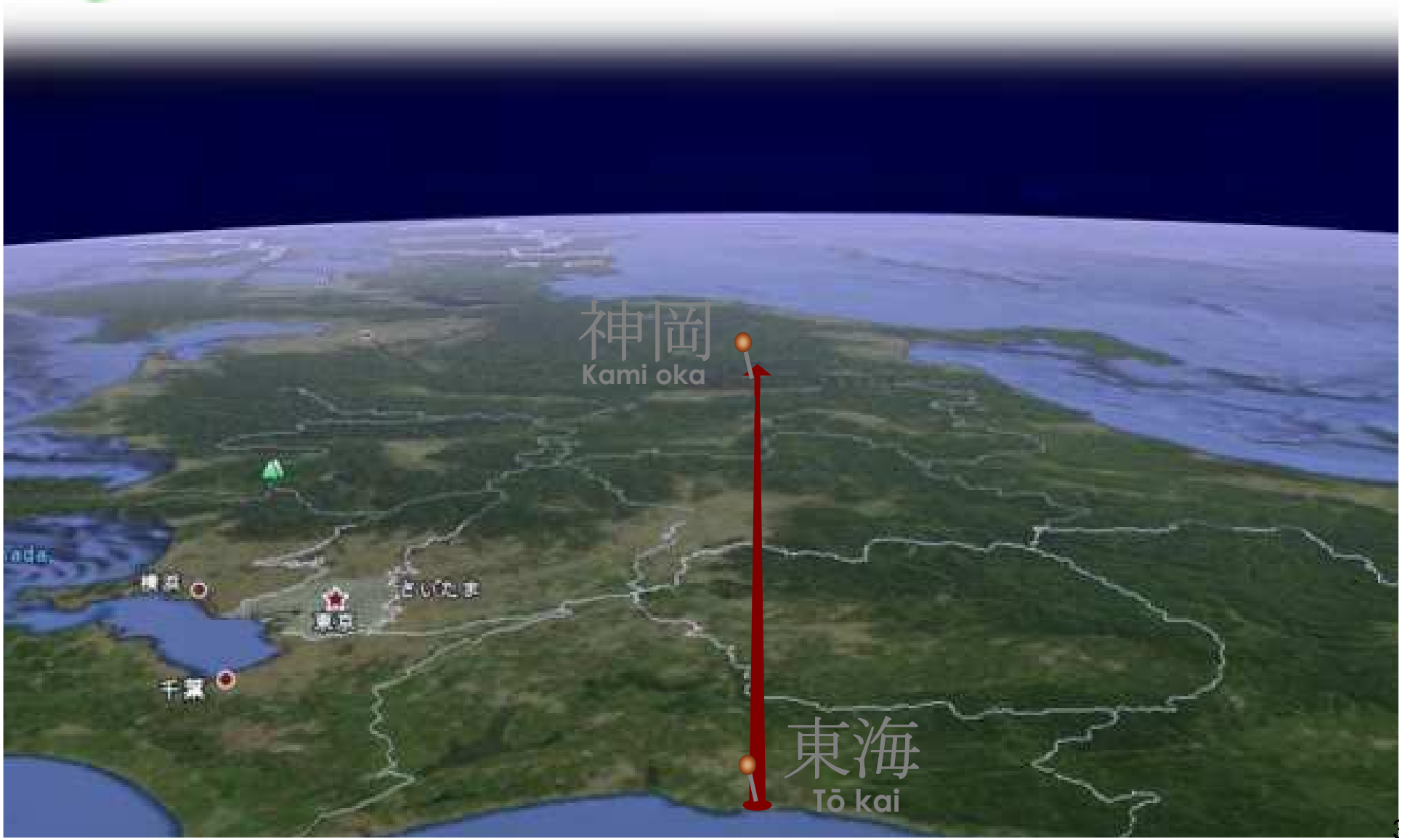


Idea of T2K was born 1999-2001 hep-ex/0106019 combining:

-- existing SuperKamiokande detector (50kton W.Č., 22.5 kton fiducial)

-- JAERI-KEK Japanese Proton Accelerator Research Complex (JPARC) at TOKAI including a high power, 0.75MW/50GeV Proton Synchrotron

-- baseline 295 km ➔ neutrino energy for first maximum is ~600 MeV achievable by pion-decay beam at 2.5 degrees off-axis


神岡
Kami oka
東海
Tō kai

~500 members, 61 Institutions, 12 countries

Canada
TRIUMF
Univ. Alberta
Univ. Brit. Columbia
Univ. Regina
Univ. Toronto
Univ. Victoria
York Univ.

France
CEA Saclay
IPN Lyon
LLR E. Poly.
LPNHE Paris

Germany
Univ. Aachen

Italy
INFN, Univ. Rome
INFN, Univ. Naples
INFN, Univ. Padua
INFN, Univ. Bari

Japan
ICRR Kamioka
ICRR RCCN
KEK
Kobe Univ.
Kyoto Univ.
Miyagi Univ. of Educ.
Osaka City Univ.
Univ. Tokyo

Poland
Soltan Inst., Warsaw
Niewodniczanski Inst., Cracow
Technical Univ. Warsaw
Univ. Silesia, Katowice
Univ. Warsaw
Univ. Wrocław

Russia
INR

S. Korea
N. Univ. Chonnam
Univ. Dongshin
Univ. Sejong
N. Univ. Seoul
Univ. Sungkyunkwan

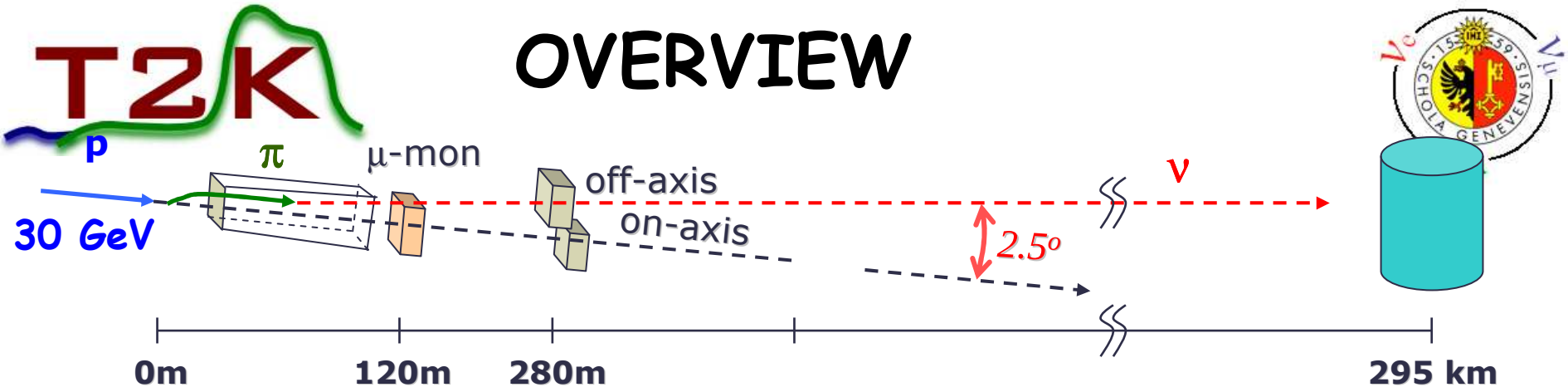
Spain
IFIC, Valencia
Univ. A. Barcelona

Switzerland
Univ. Bern
Univ. Geneva
ETH Zurich

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

USA
Boston Univ.
BNL
Colorado St. Univ.
Duke Univ.
Louisiana St. Univ.
SUNY-Stony Brook
U. C. Irvine
Univ. Colorado
Univ. Pittsburgh
Univ. Rochester
Univ. Washington

OVERVIEW

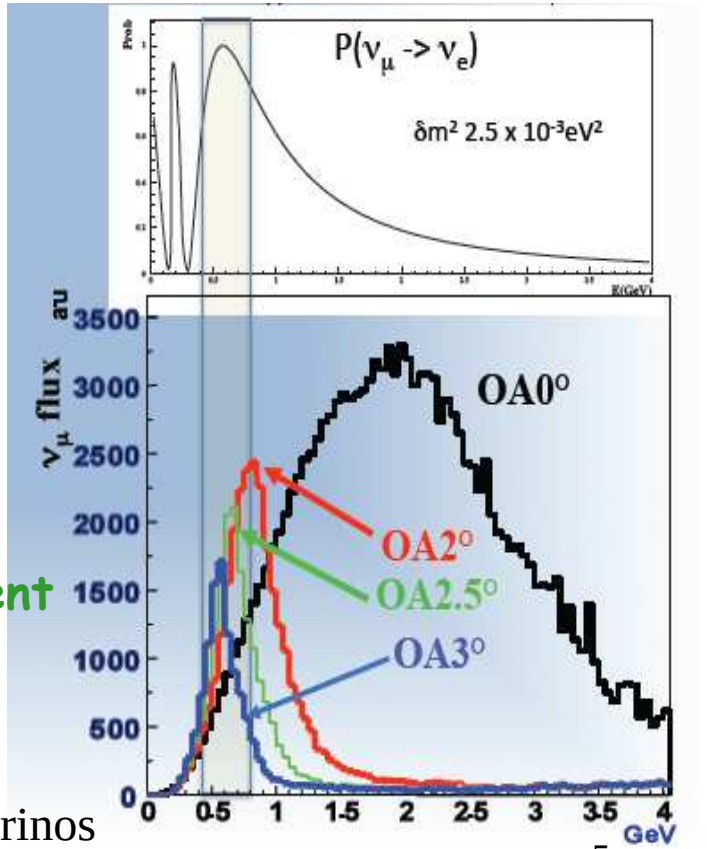


- **2.5 degrees off-axis beam**
  - Low energy, narrow band beam tuned at osc. max.
  - Neutrino peak ~600 MeV/c
- **MUMON** @ 120 m from target, high E muons

⇒ measures beam direction (to <1 mrad)

- **Near detector @ 280 m from target**

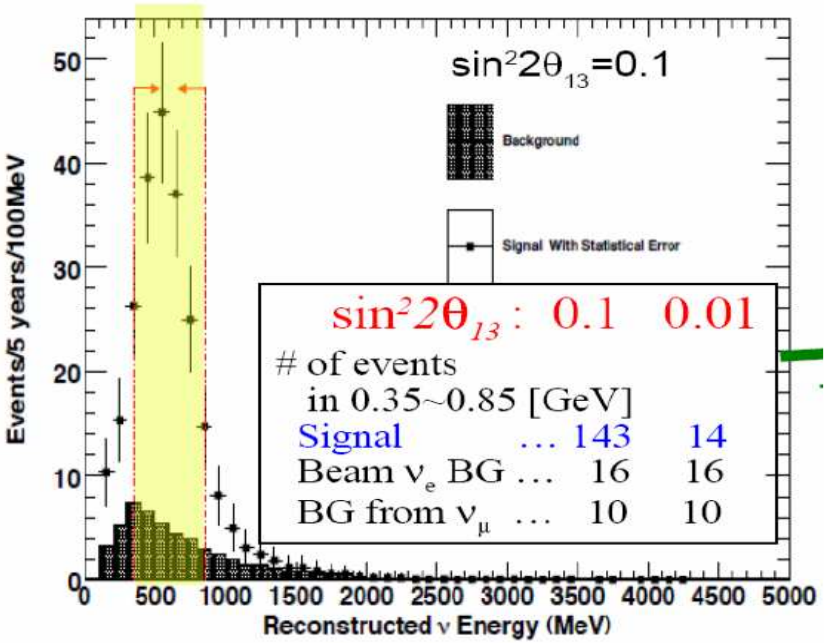
⇒ extrapolate ν energy spectrum and flux to SK
  - **INGRID:** on axis to monitor beam direction
  - **ND280:** off axis to measure ν_μ and ν_e interaction rates and backgrounds
- **NA61 at CERN→ hadro-production measurement** see Sebastien Murphy's talk
- **Far detector SuperKamiokande @ 295 km**
  - Very large water Cerenkov detector
  - Very good μ/e separation capability for sub-GeV neutrinos



T2K physics goals

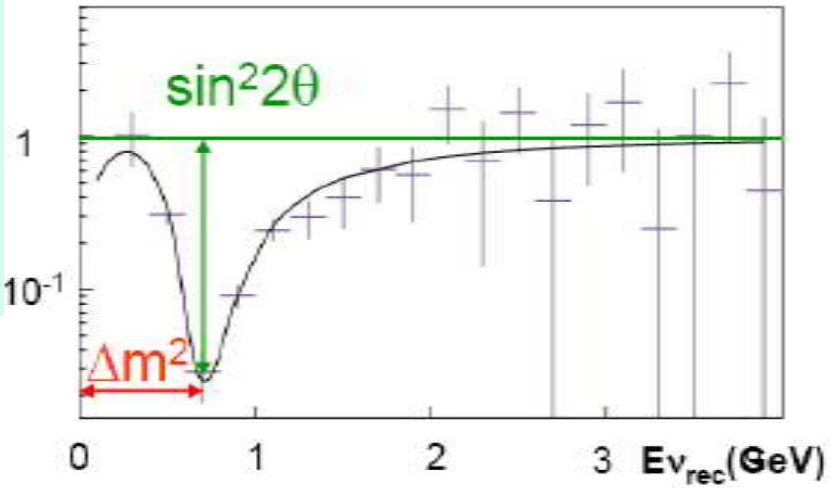
Experiment is optimized for the search of $\nu_\mu \rightarrow \nu_e$ oscillation ➔ θ_{13}

$P(\nu_\mu \rightarrow \nu_e) \cong \sin^2 2\theta_{13} \sin^2 \theta_{23} \sin(1.27\ \Delta m^2_{23}\ L/E_\nu)$



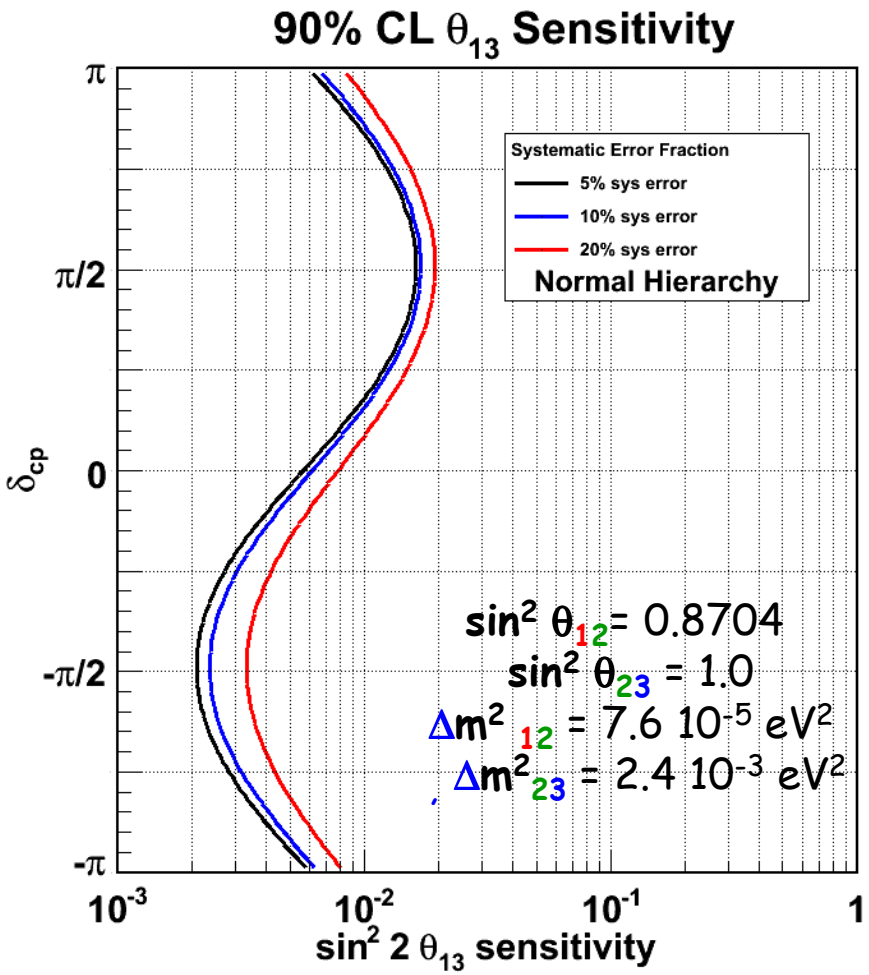
-- is also able of precision measurement of $\nu_\mu \rightarrow \nu_\mu$ oscillation ➔ θ_{23} , Δm^2_{23}

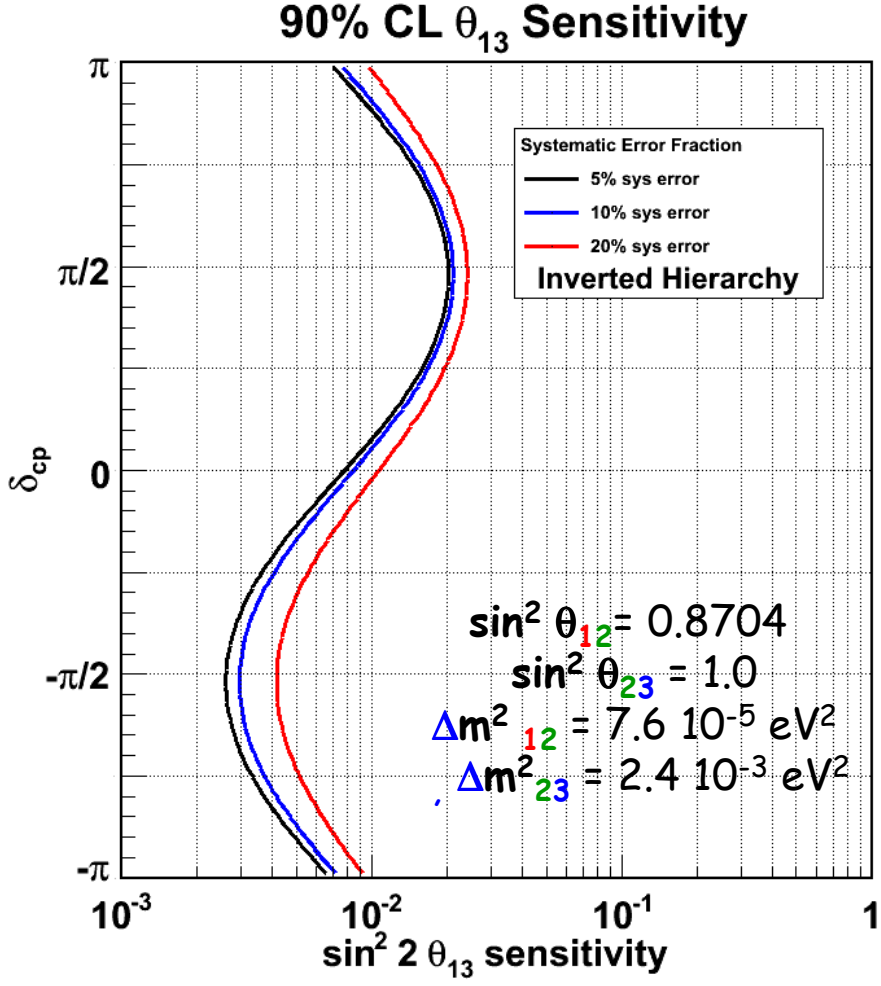
$P(\nu_\mu \rightarrow \nu_\mu) \cong 1 - \sin^2 2\theta_{23} \sin(1.27\ \Delta m^2_{23}\ L/E_\nu)$



-- and measurements of cross-sections around 600 MeV in the near detector

θ_{13}

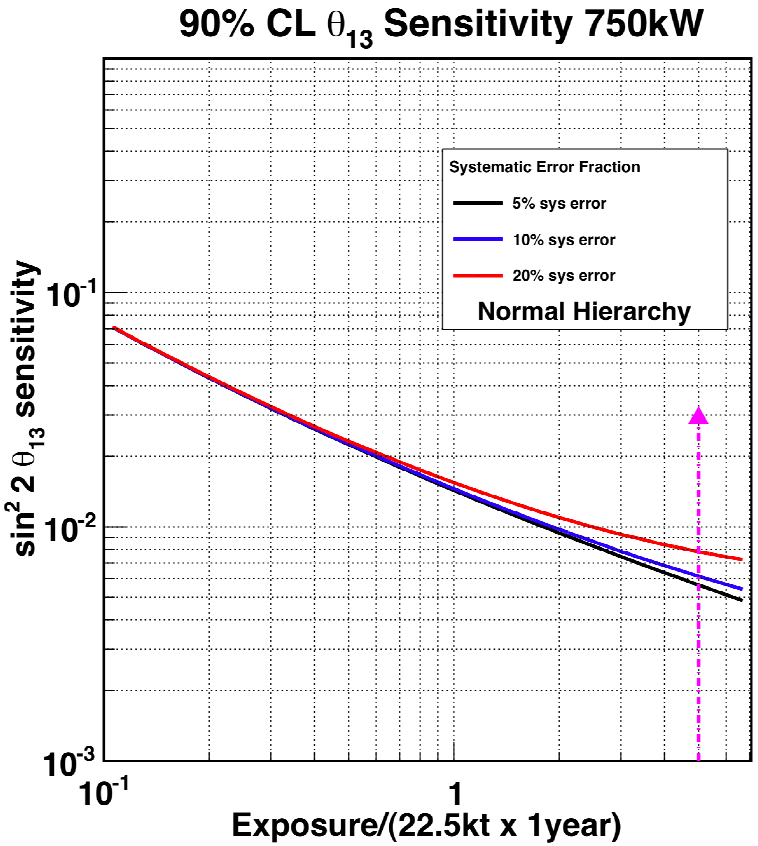




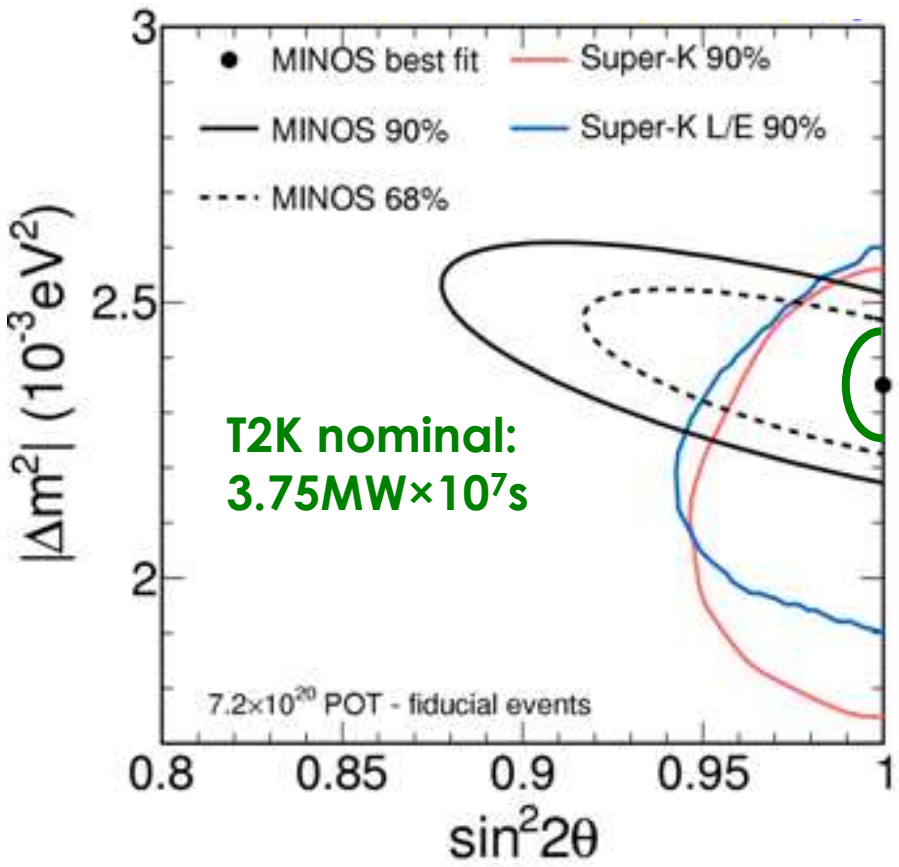
90% C.L. 750kW X 5 years X 22.5 kton fid.

short baseline ➔ little sensitivity to matter effects, but sensitive to δ_{CP}

Appearance: Dis-appearance



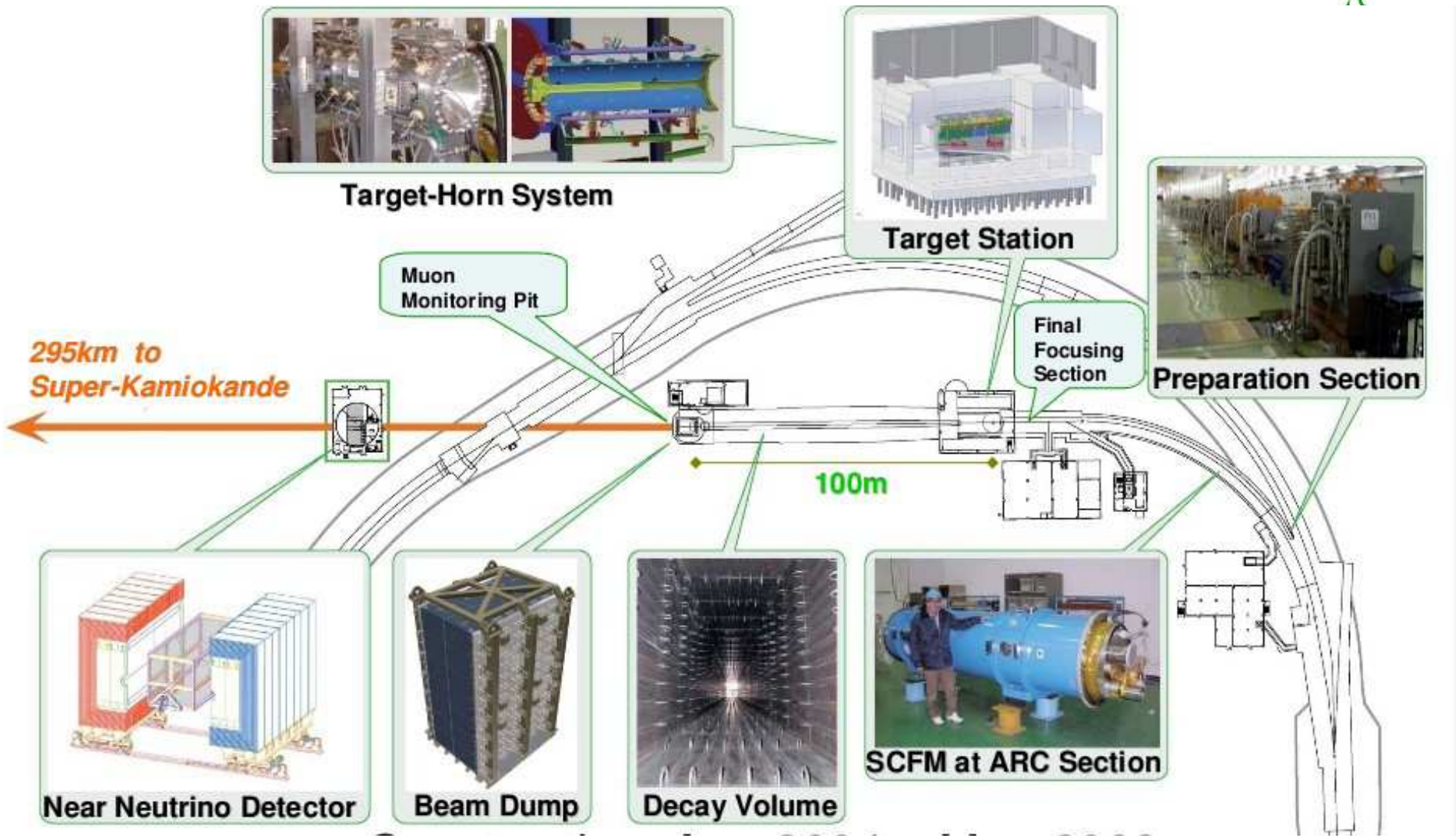
MINOS & Super-K preliminary @ Nu'10



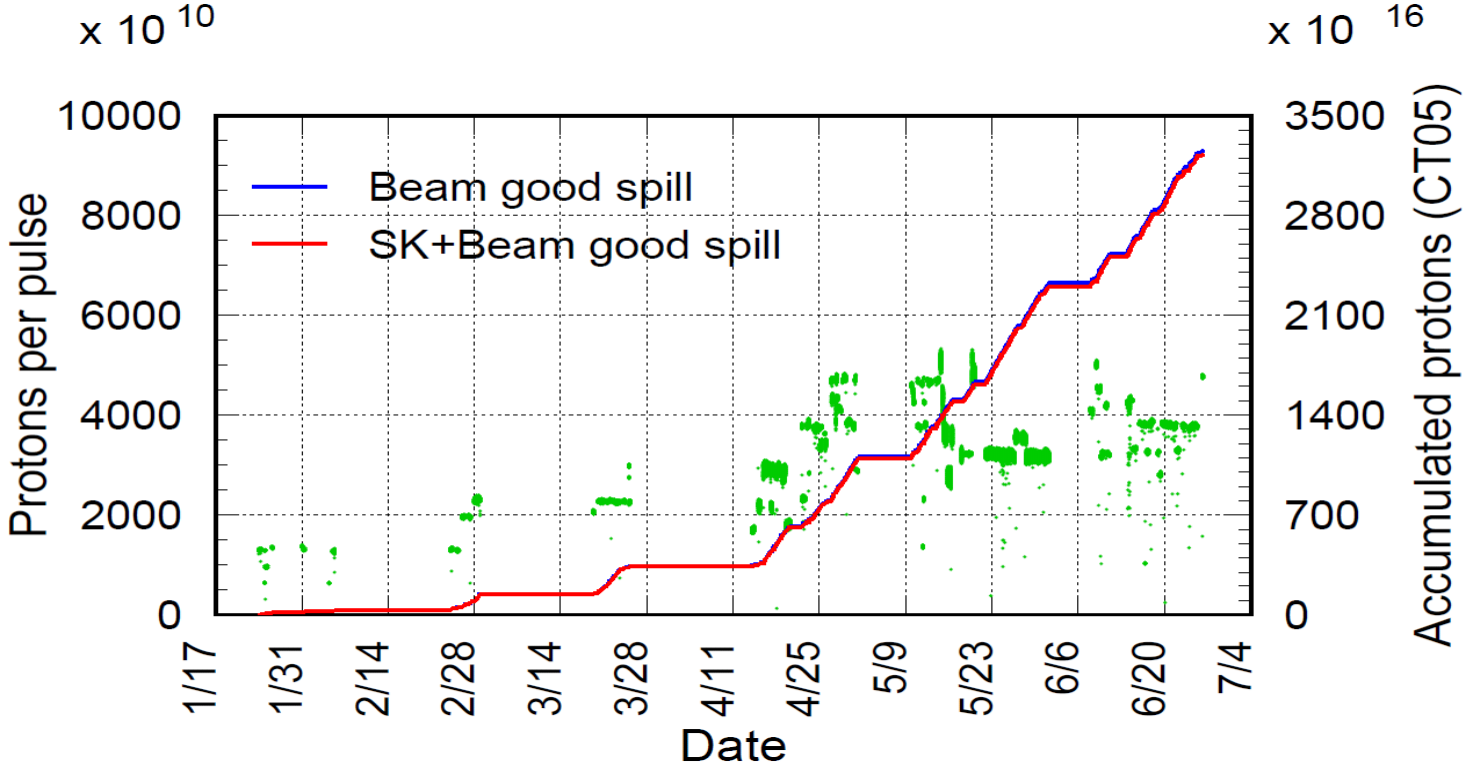
$\sin^2 2\theta_{13} < 0.008$ (90% C.L.)
for 5 years@750kW
= 8.3 10^{21} p.o.t@30 GeV

spectrum centered on oscillation maximum
➔very rapidly sensitive to Atm. Params.
$\Delta\sin^2 2\theta_{23} \approx 0.01$
$\Delta m^2_{23} < 1\times10^{-4}$ eV^2

Beam Line


Target-Horn System
Target Station
Preparation Section
Muon
Monitoring Pit
Final
Focusing
Section
295km to
Super-Kamiokande
100m
Near Neutrino Detector
Beam Dump
Decay Volume
SCFM at ARC Section

Accumulated protons



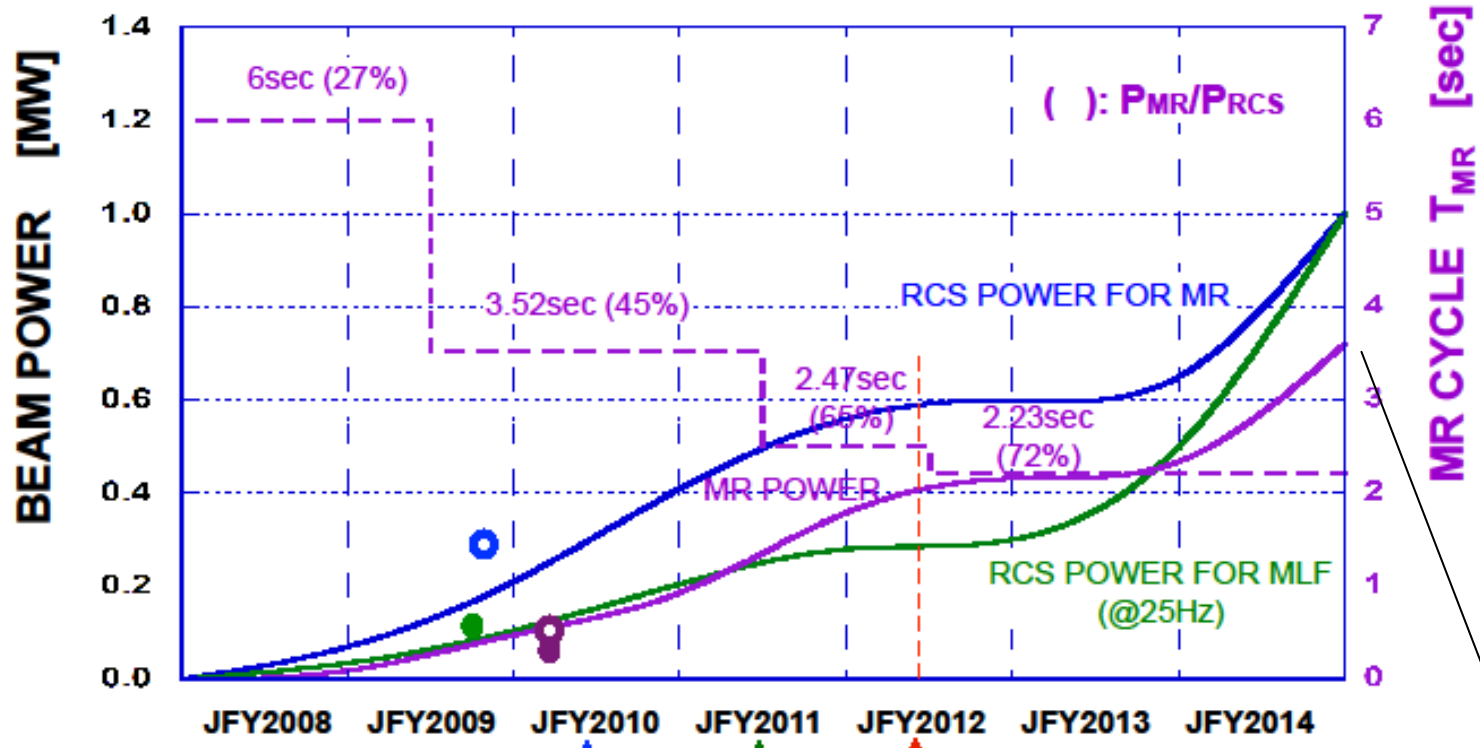
First T2K run completed (January to June 2010)

- 3.23 ×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 ×10^{7} sec by July 2011

Present limitations :
extraction kickers → changed to faster ones in summer 2010
Radiation issues → go slow, work on collimation

Power upgrade plan of RCS and MR(FX)

For 8 bunches, 30 GeV at MR: $P_{MR}=1.6 \times (P_{RCS}/T_{MR})$



3-50BT collimator shields, RF (1st HH), FX kickers

Ring collimator shields, RF (6th F, 2nd HH), Inj. Sep 1

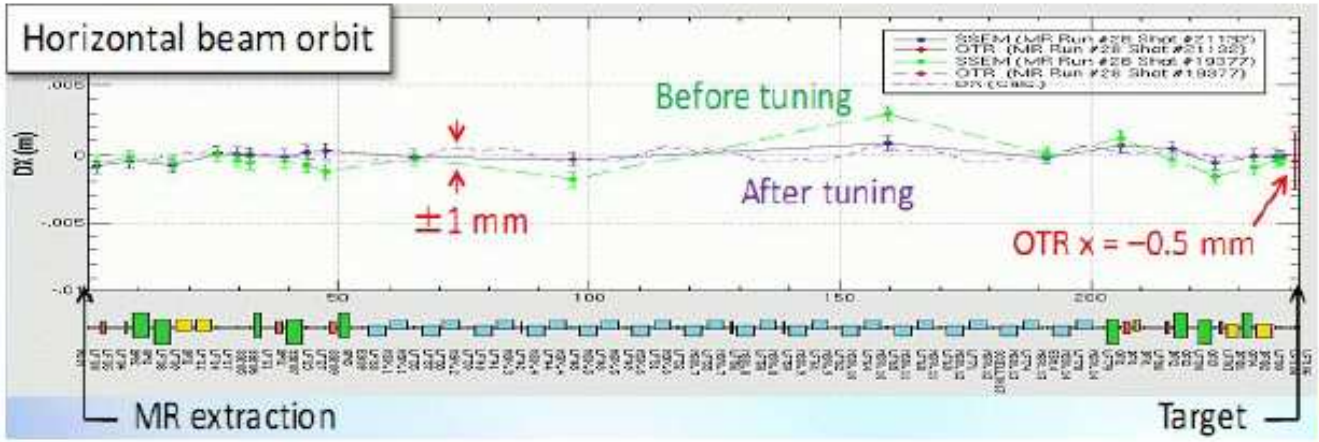
ACS Installation in JFY2012
400 MeV injection in the RCS

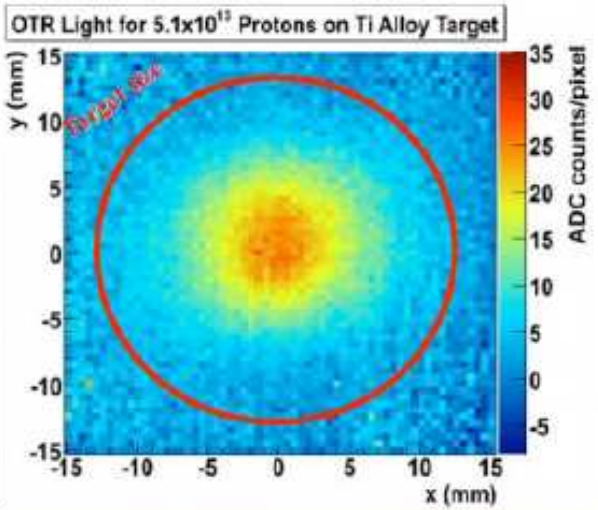
RF (3rd HH), Inj. Sep 2, FX Septa,

750kW in 2014

Beam Monitors

Proton beam precisely tuned (<1mm) to minimize beam loss, and control direction of secondary beam

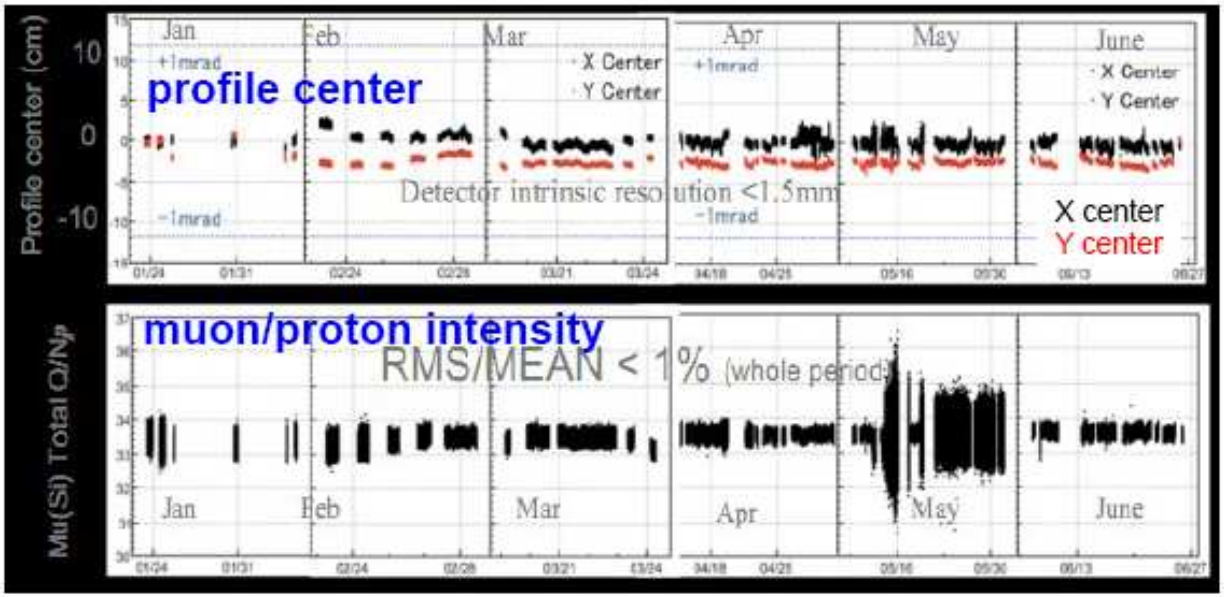




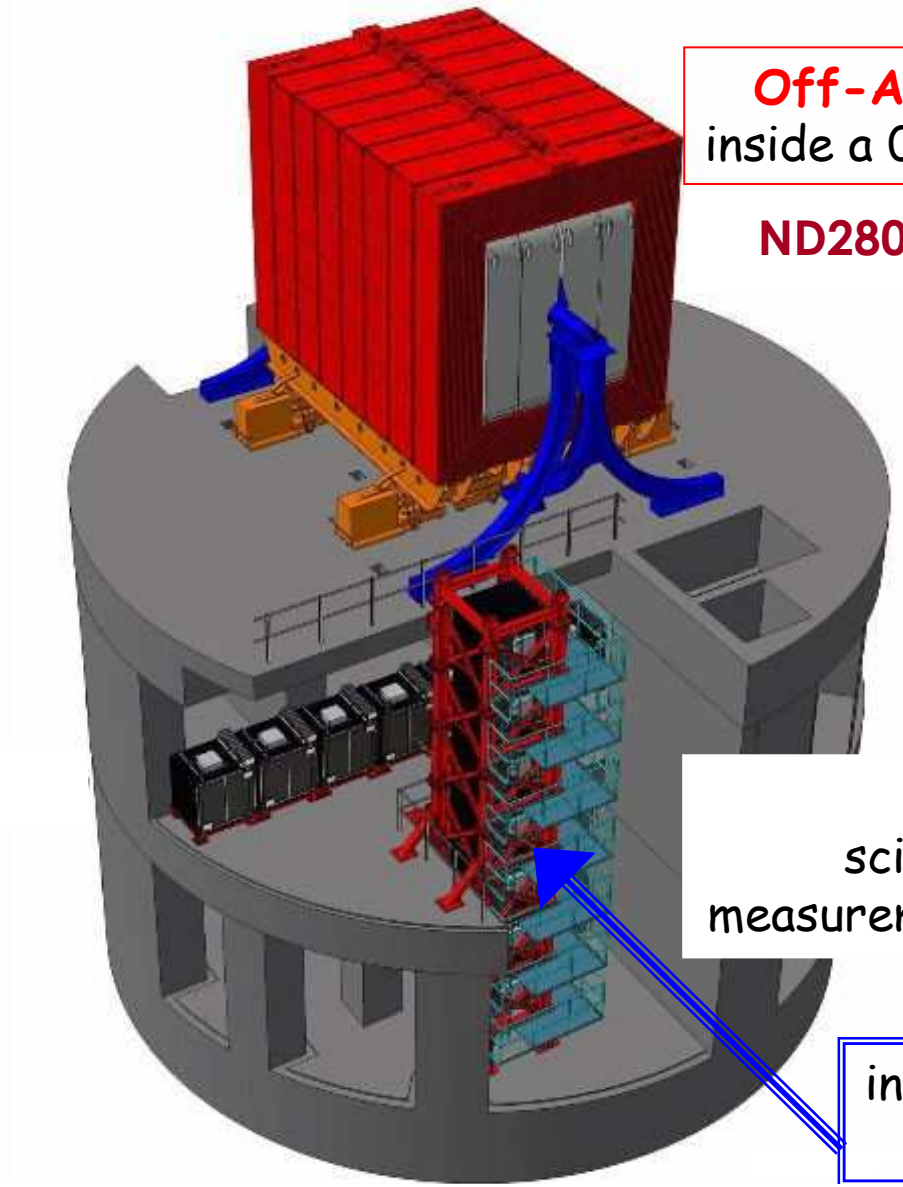
Optical transition radiation detector (OTR) immediately upstream of target:

Muon monitors (SiPIN and ionization chambers):

- measure beam direction and intensity spill-by-spill
- requirement: <1mrad (ΔE_ν^{peak} ~ 2%/mrad)



Near Detector Complex ND280



Off-Axis suite of fine grain detectors/tracker inside a 0.2 T magnetic field (UA1/NOMAD magnet)

ND280:

measurements of
-- CCν_μ events
(normalization, disappearance)

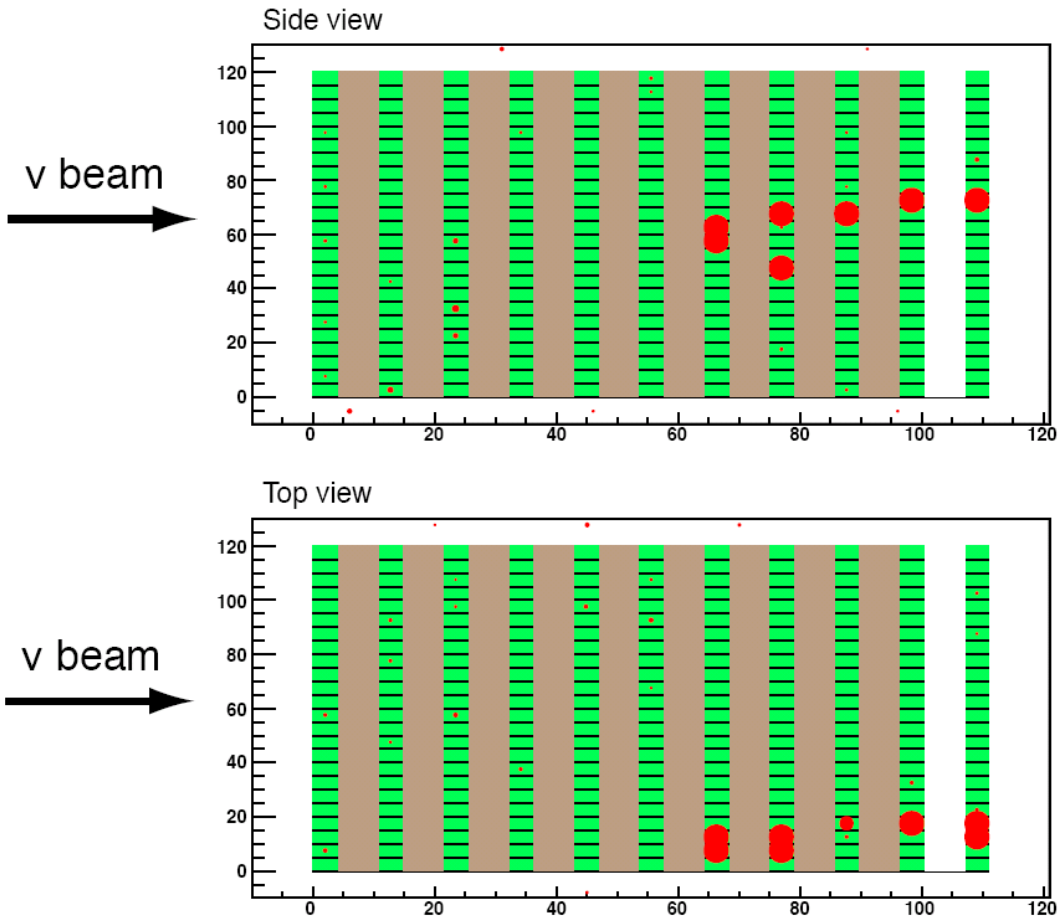
-- CCν_e events
-- π^0 events
Backgrounds to $\nu_\mu \rightarrow \nu_e$ search

On-axis INGRID
scintillator-iron detectors
measurement of beam angular profile

incoming neutrino beam

IN GRID

INGRID first neutrino event candidate

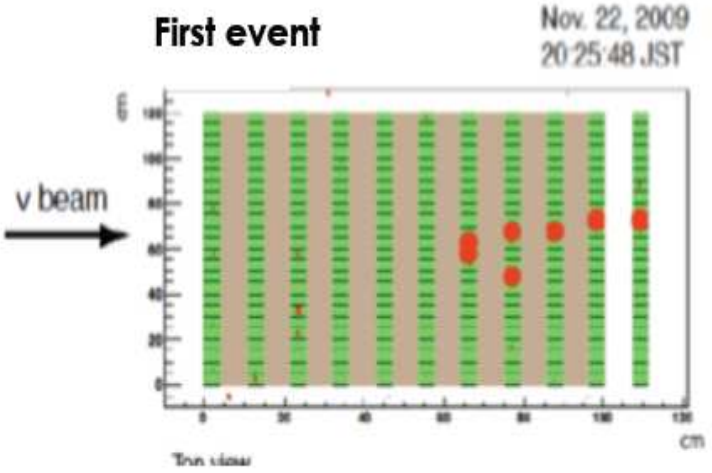


Nov. 22, 2009

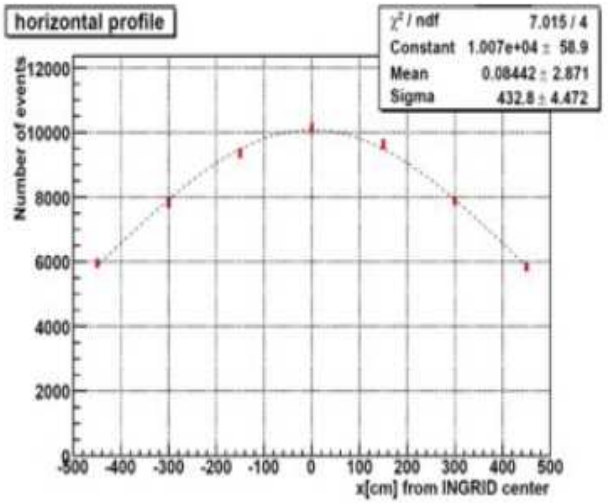
MR Shot #19655
T2K Spill# 241792

INGRID: MONITORING BEAM WITH NEUTRINO EVENTS

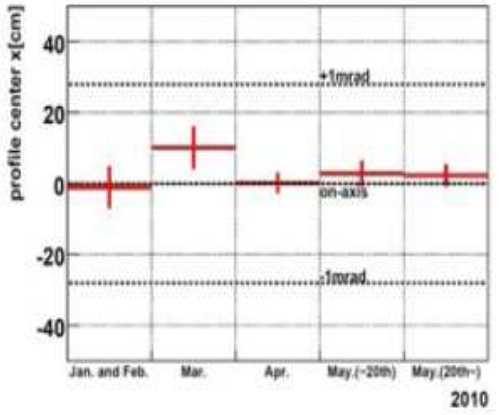
First event



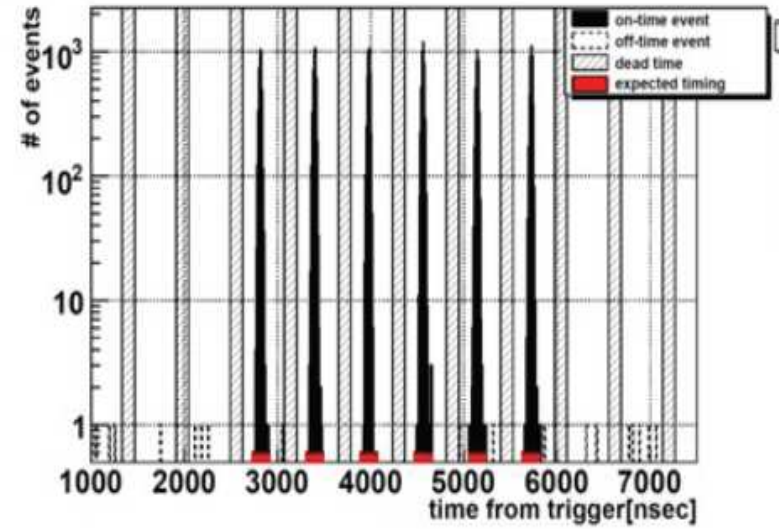
Beam Profile X



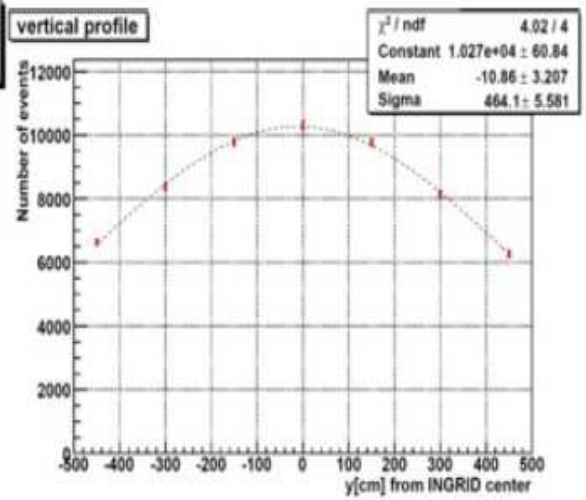
Beam Profile Center X



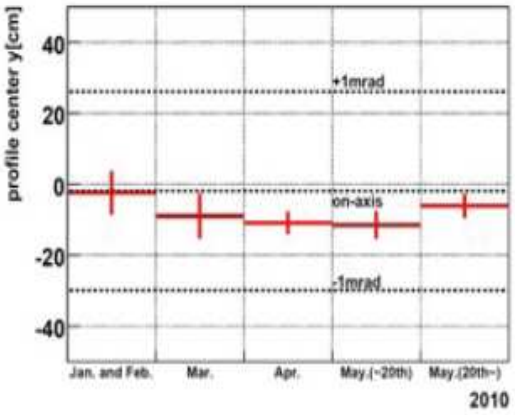
event timing after neutrino event selection



Beam Profile Y

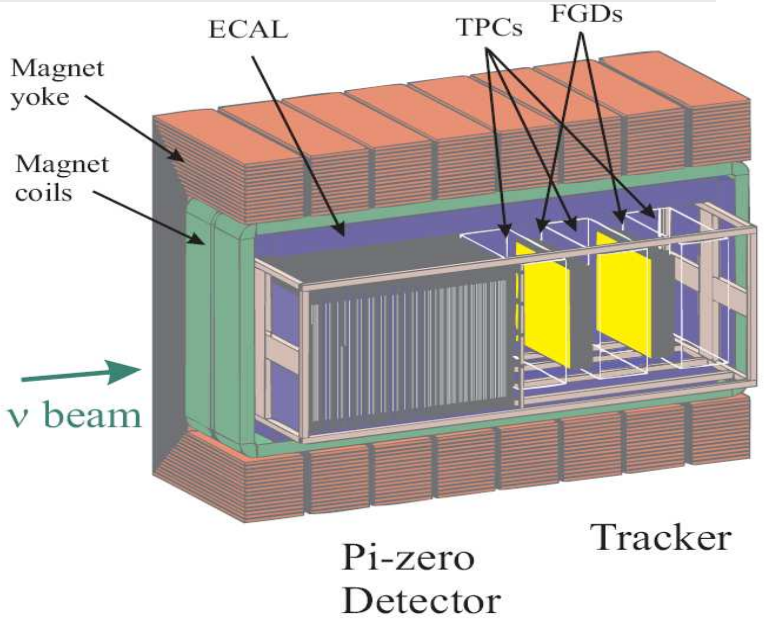


Beam Profile Center Y

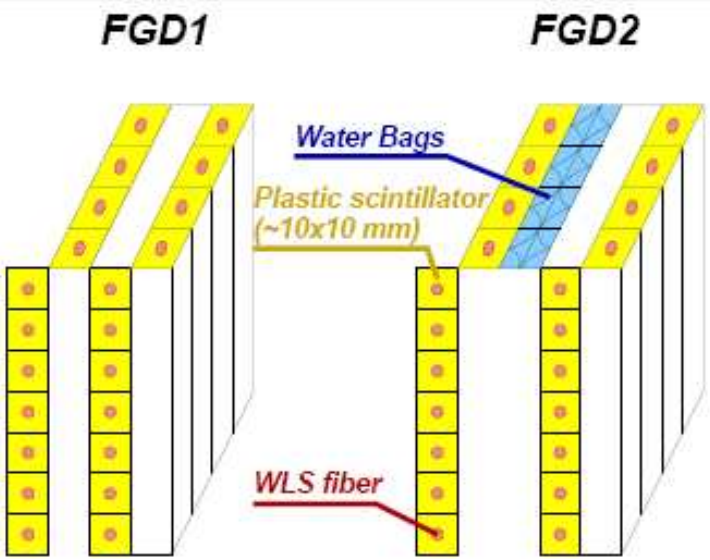


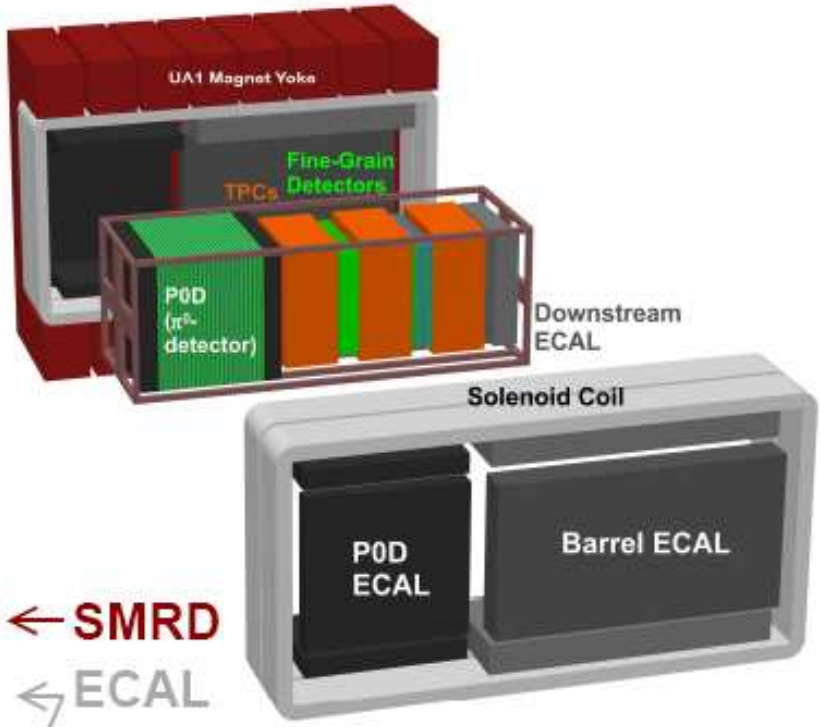
The Off-Axis Near Detector

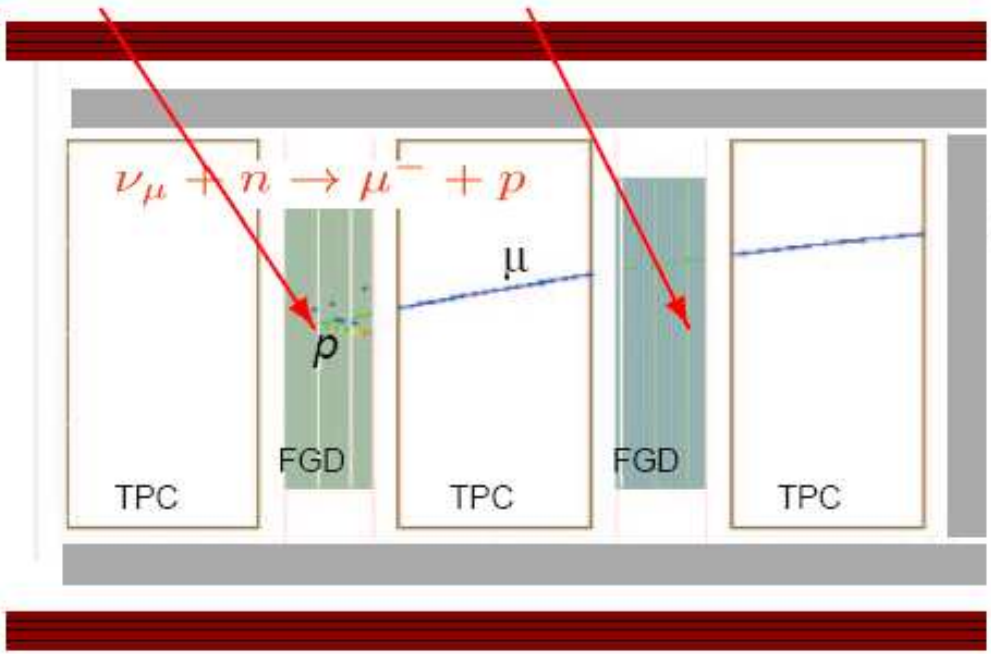
Cannot be Water Cherenkov:
-- pile-up
-- (worse) granularity of
small vs large detector



fine grain detector of light material (even water!)
-- Scitillators with MPPC readout
(60'000 channels!)
-- TPC tracker







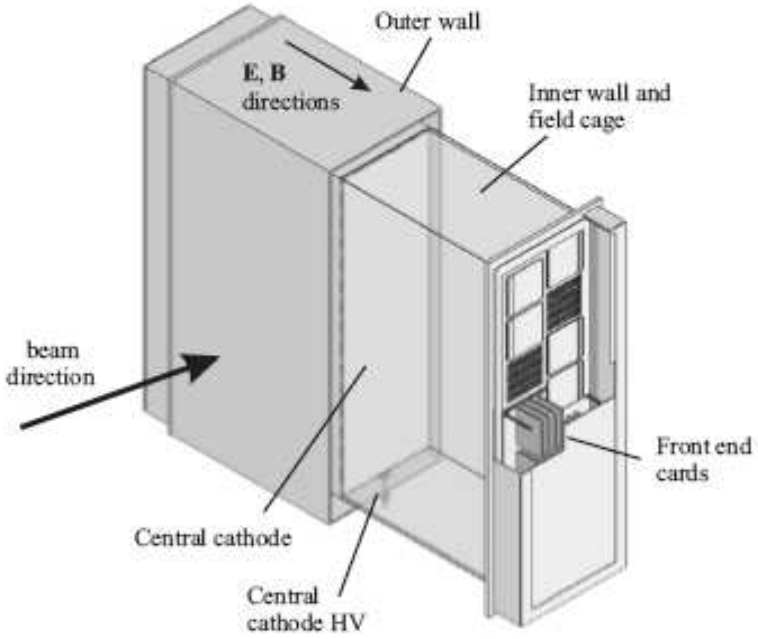
FGD: 2 × 1.3 Ton active target
- 1st FGD: plastic only
- 2nd FGD: plastic + water

→ Scintillators similar to K2K SciBar

→ Light detection by Geiger mode Avalanche Photodiodes **(MPPC)**

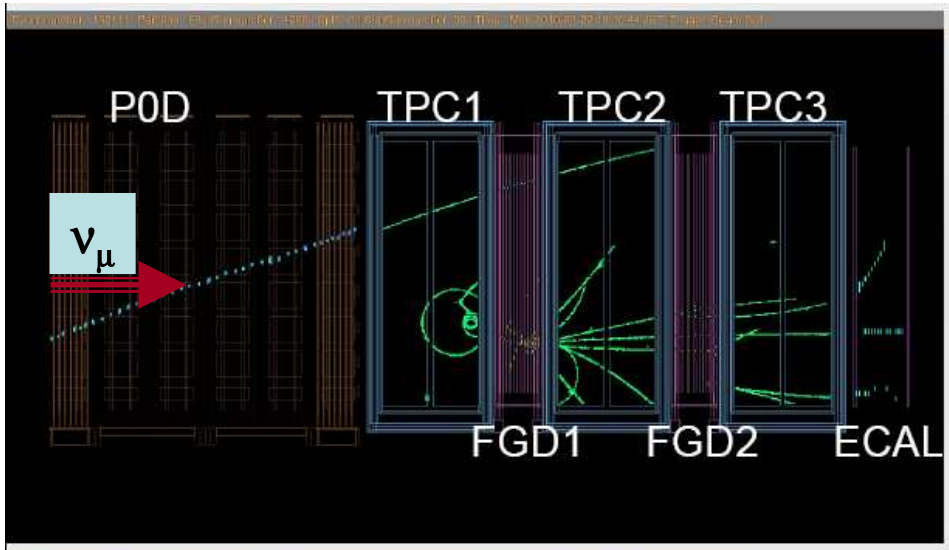
→ About 9500 channels

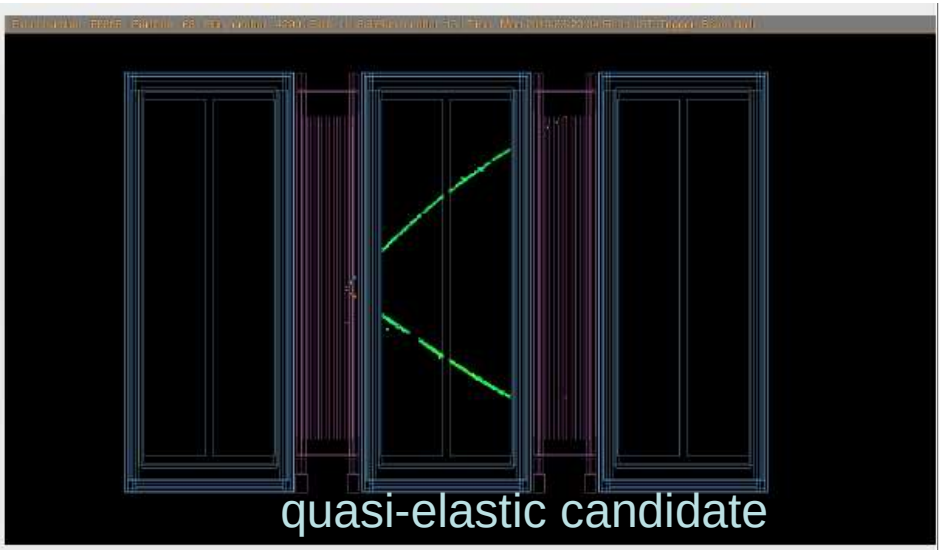
TPC's

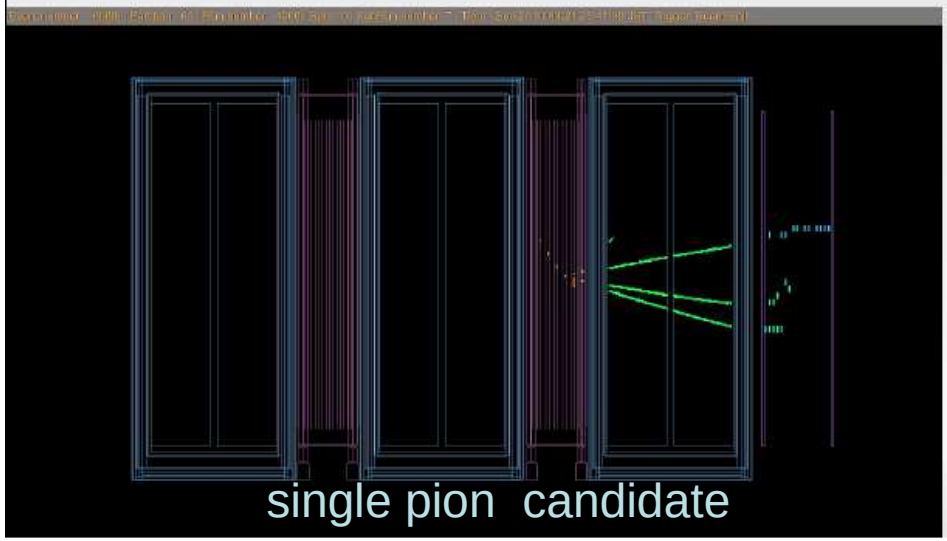


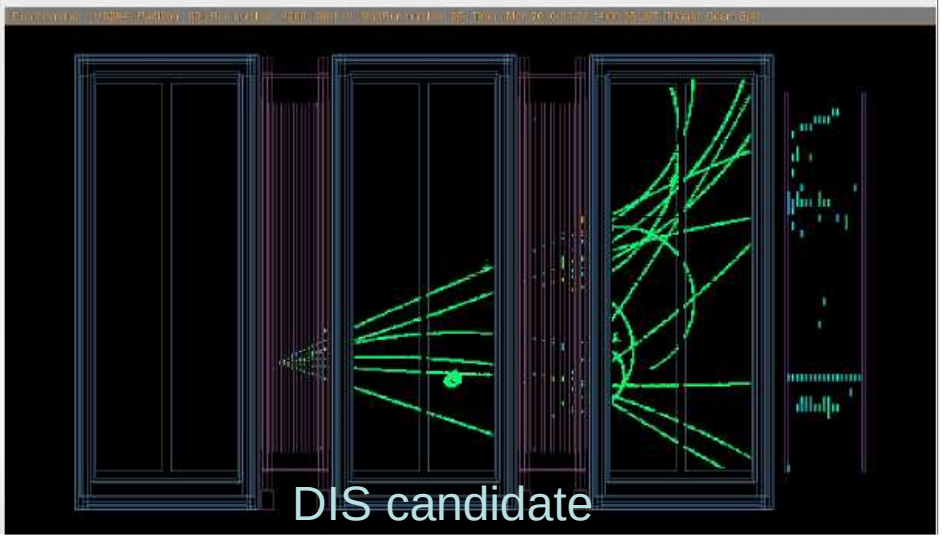
3 TPC's, 1.8 x 2 x 0.70 m^3 sensitive area
World's Largest TPC
with micro-pattern read out (MicroMeGas)

A few ND280 neutrino interaction candidates

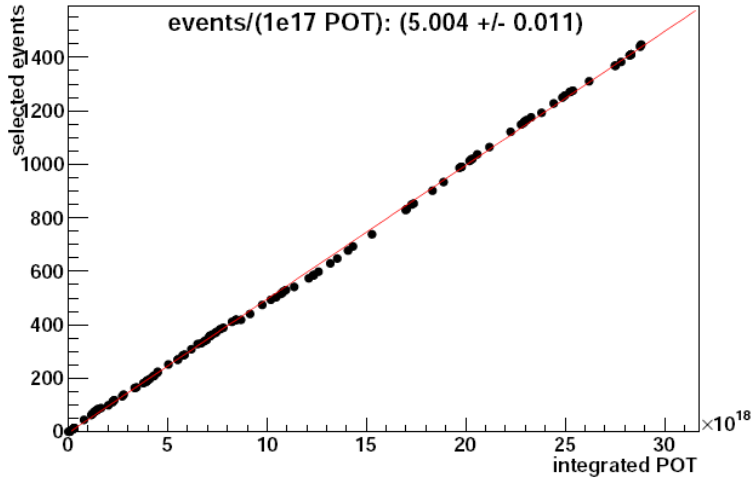



quasi-elastic candidate

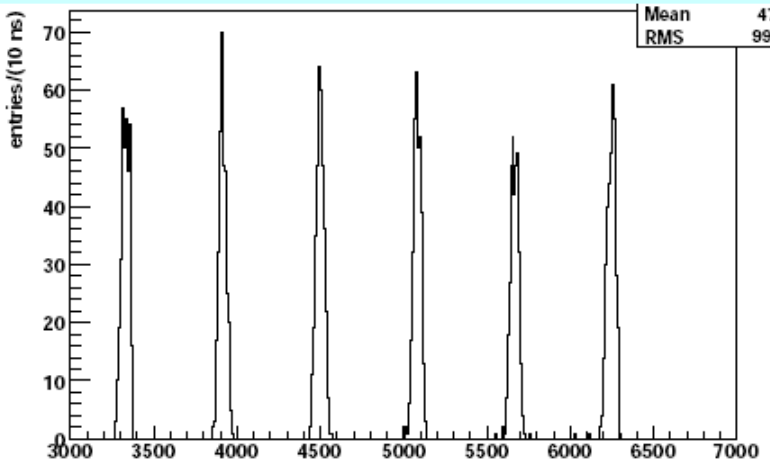

single pion candidate


DIS candidate

Interaction candidates vs p.o.t.



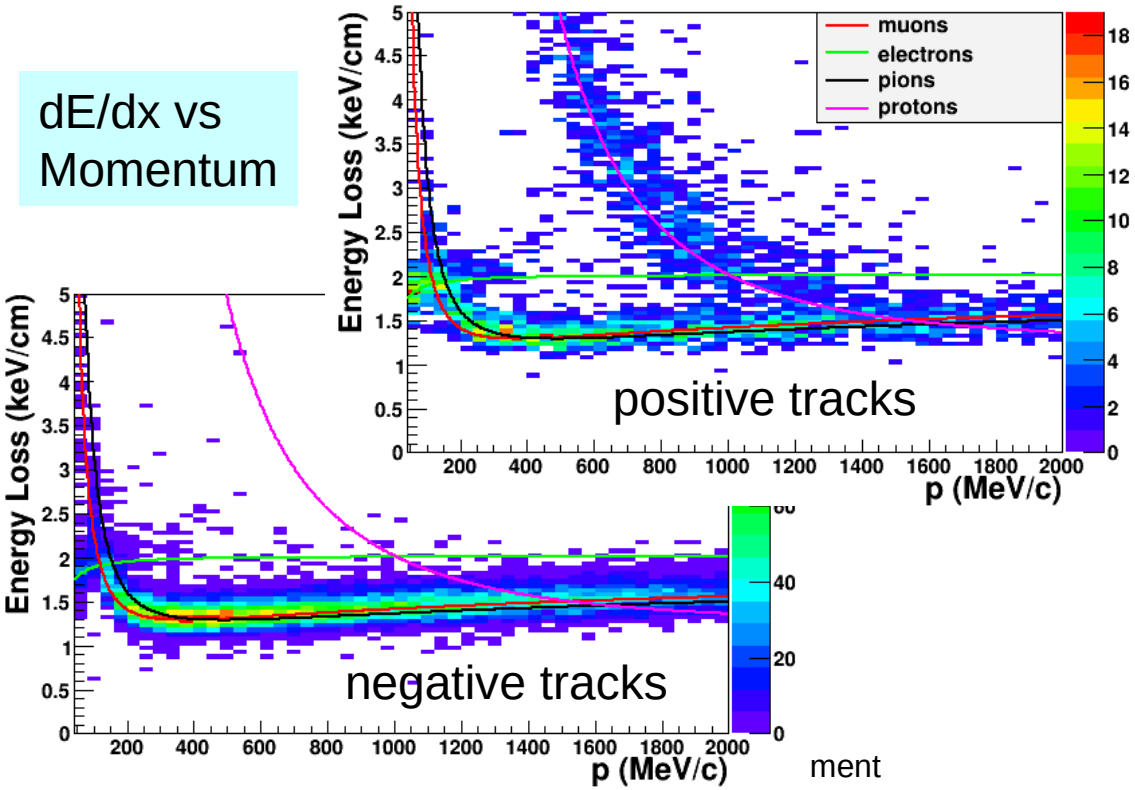
neutrino events time microstructure



time (ns) in FGD

TPC performance:

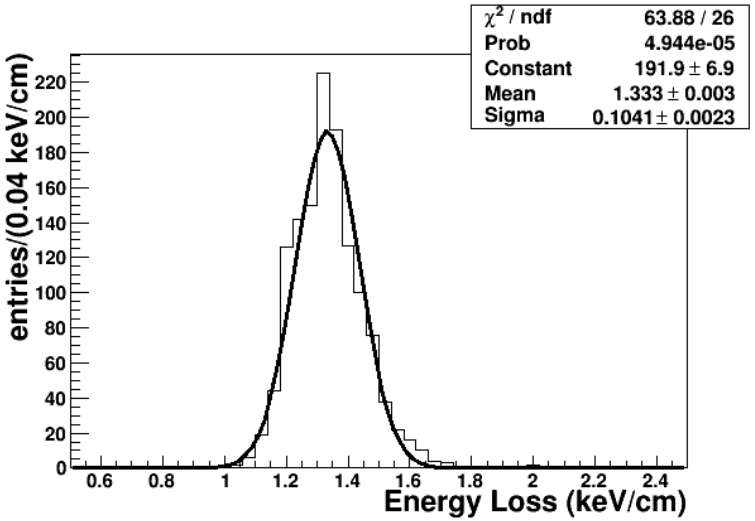
dE/dx vs Momentum



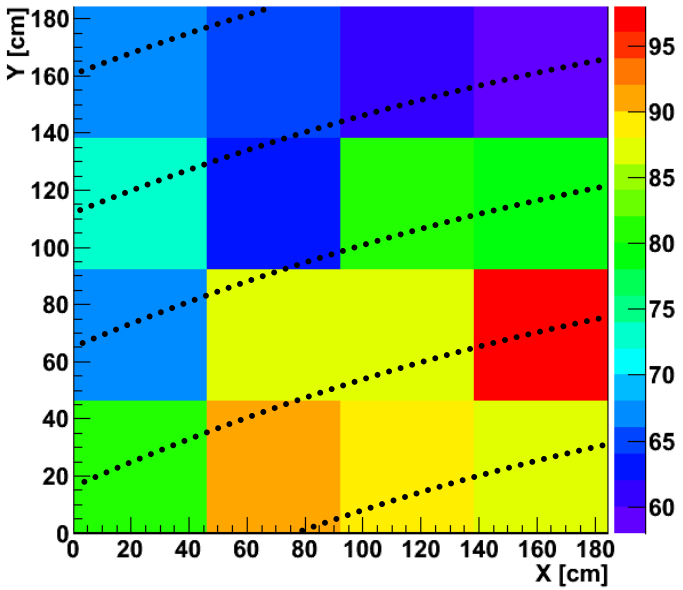
ment

ND280 performance

MIP dE/dx resolution (now) 8%

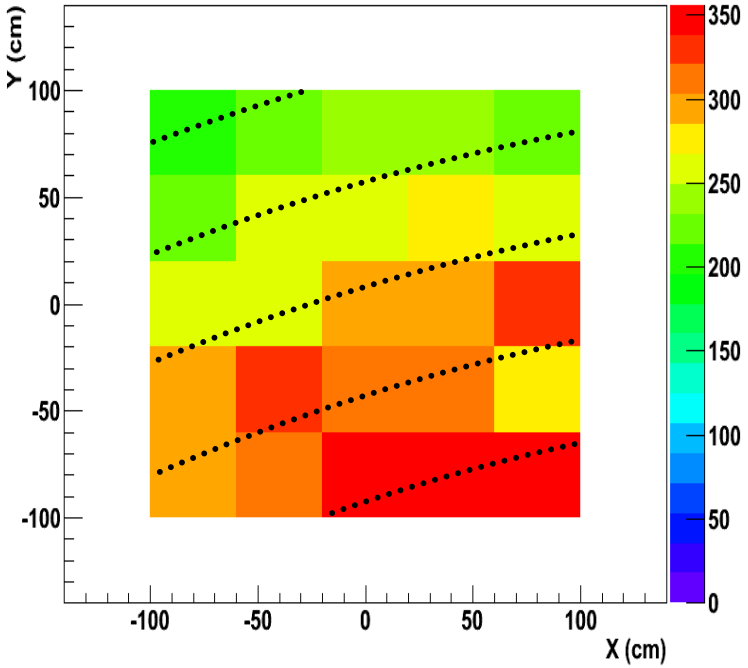


ND280 is off-axis!



◀FGD

P0D▶

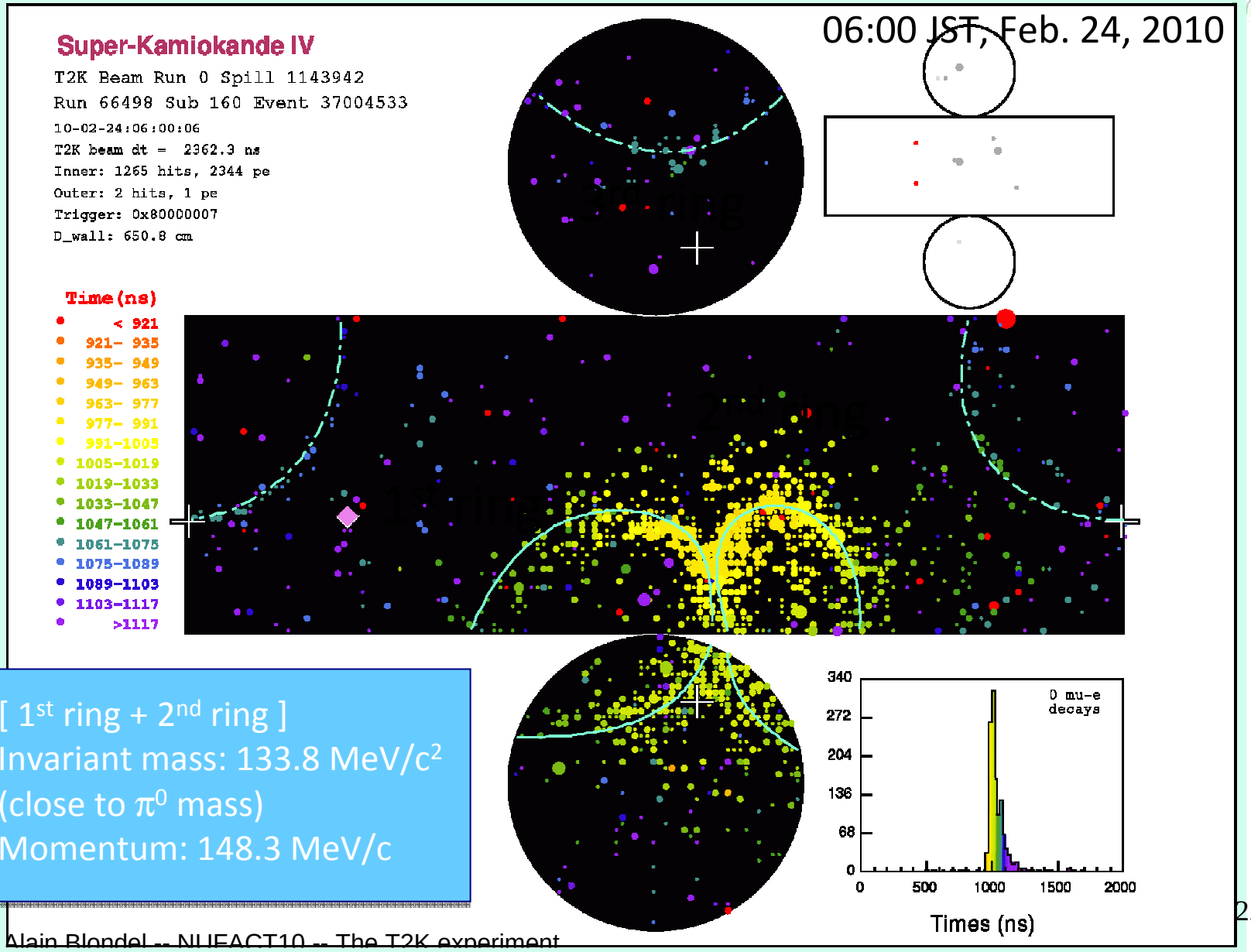


contained vertices reconstructed in the 2 'Fiducial' detectors.

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

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

T2K 1st ν event in Super-K



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

Unbiased event selection

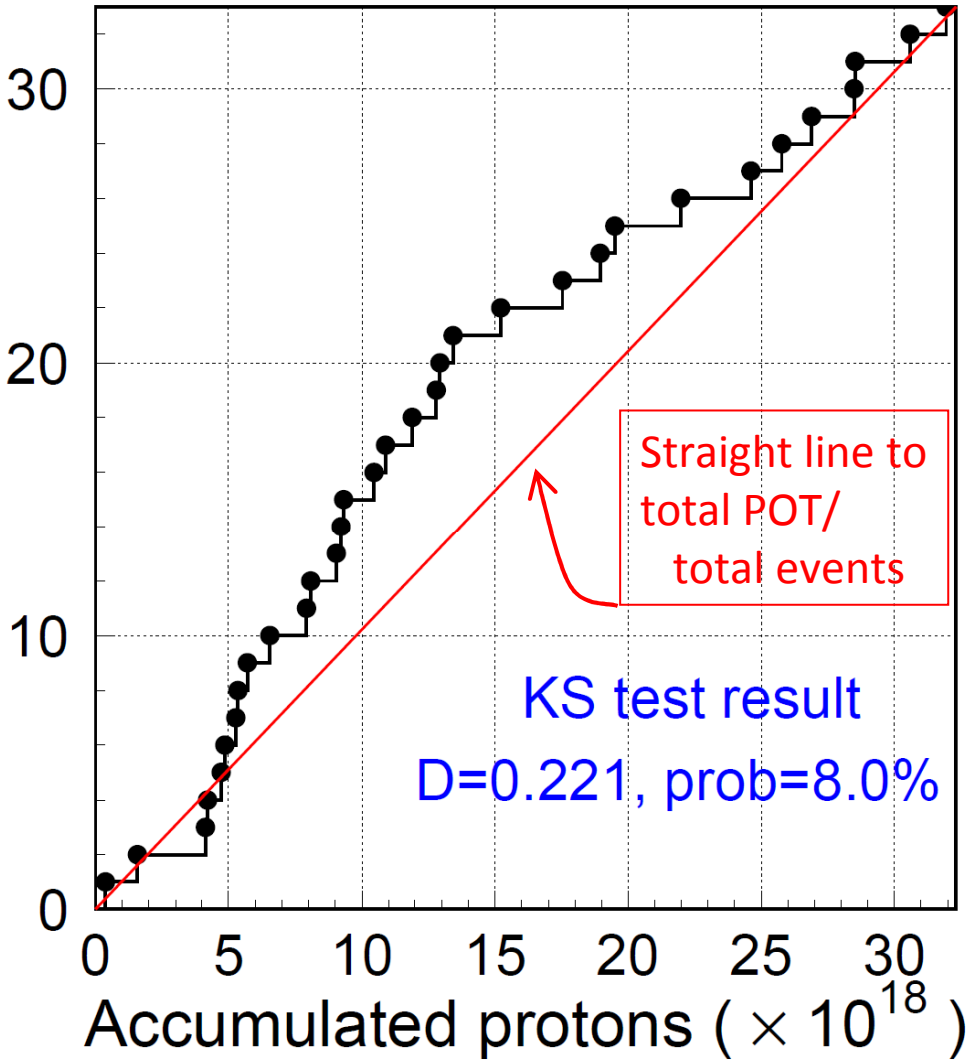
For initial run, SK event selection was fixed before run.

➔ Possible because SK is a mature & well understood detector.

For ν_μ disappearance analysis	For ν_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_ν^{rec} < 1250MeV

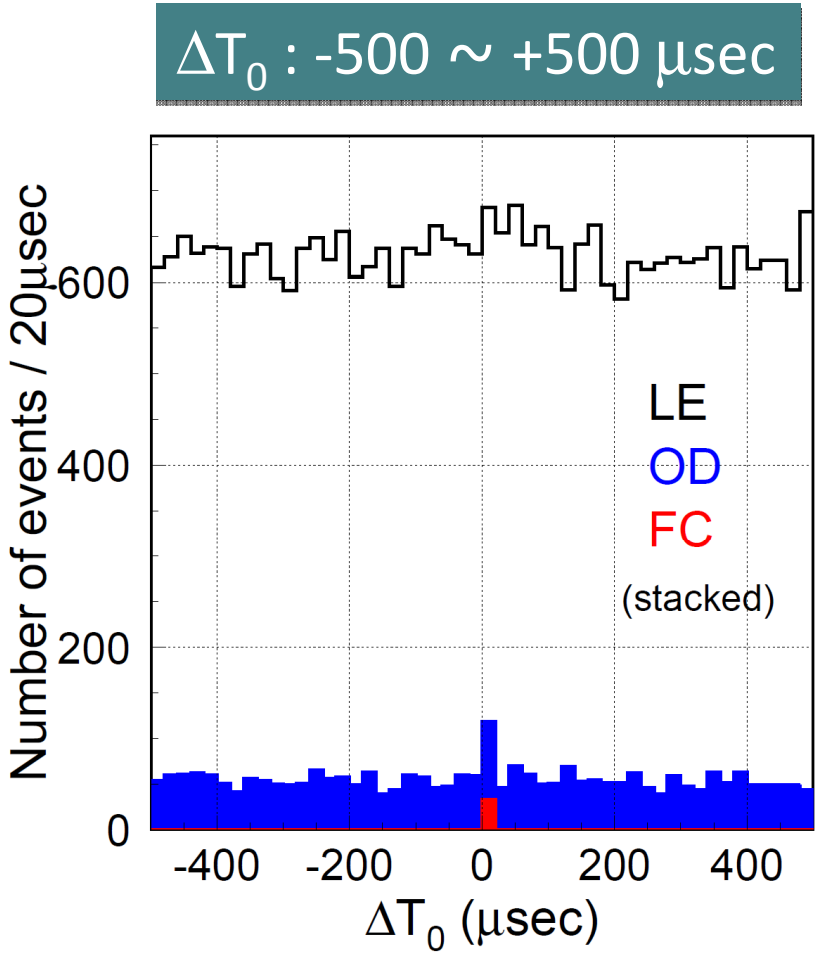
Events detected in SuperK

	Number of events
Fully-Contained (FC)	33
+ fiducial volume cut + visible ene. > 30MeV (FCFV)	23



ΔT_0 distribution

ΔT_0 : relative event time to the spill time



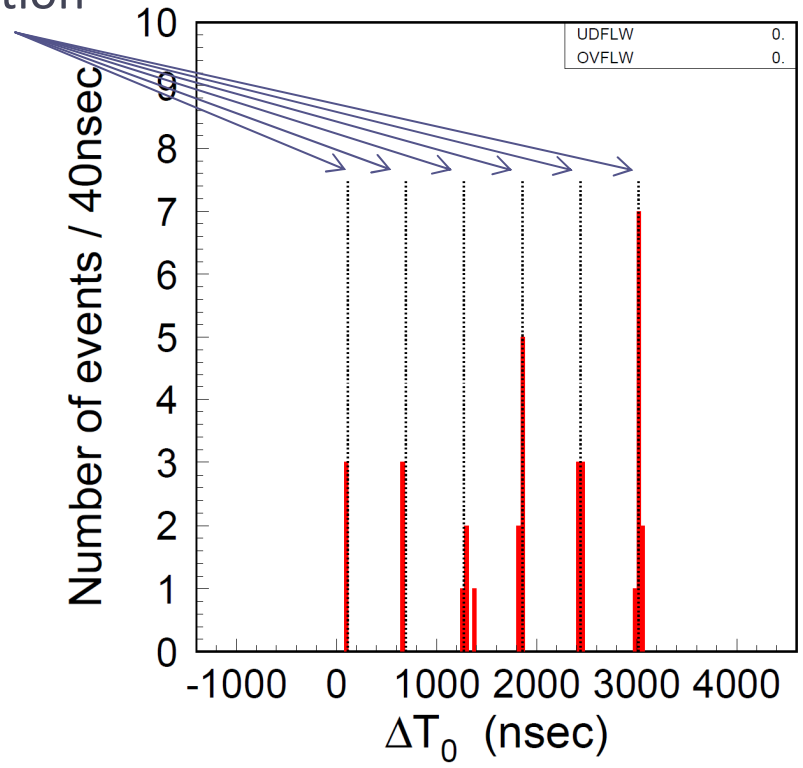
Out-of-time OD/LE rate is flat.

No out-of-time FC events.

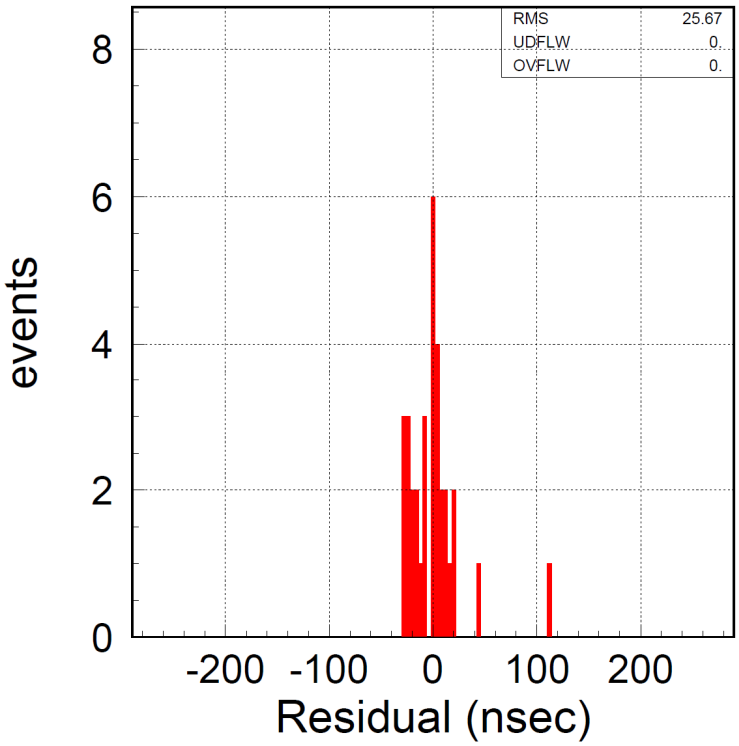
ΔT_0 distribution (FC events)

Fitted 581nsec-interval bunch position

ΔT_0



Residual from bunch position

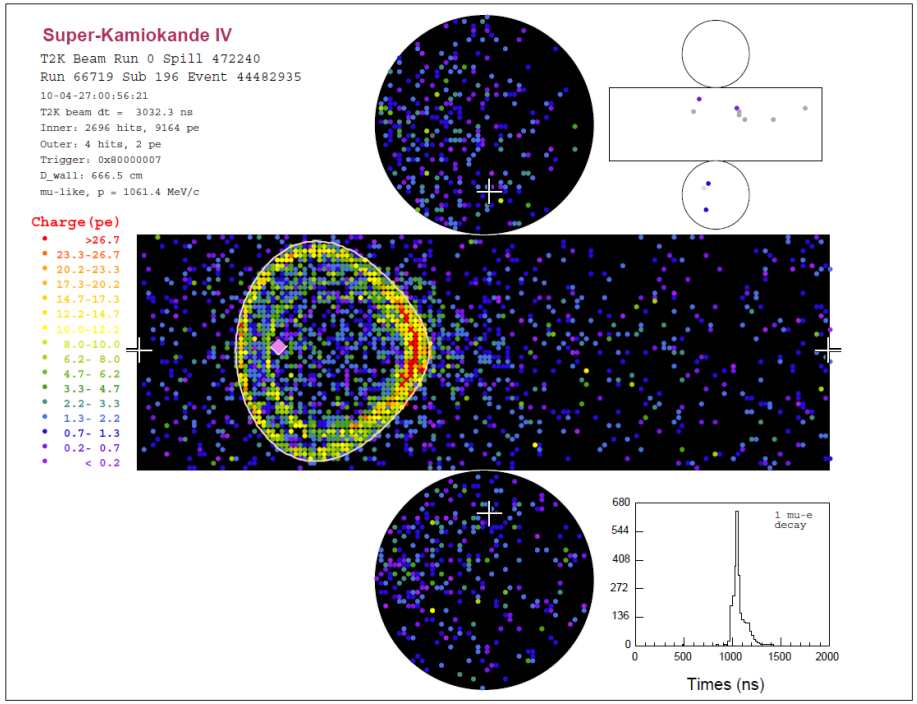


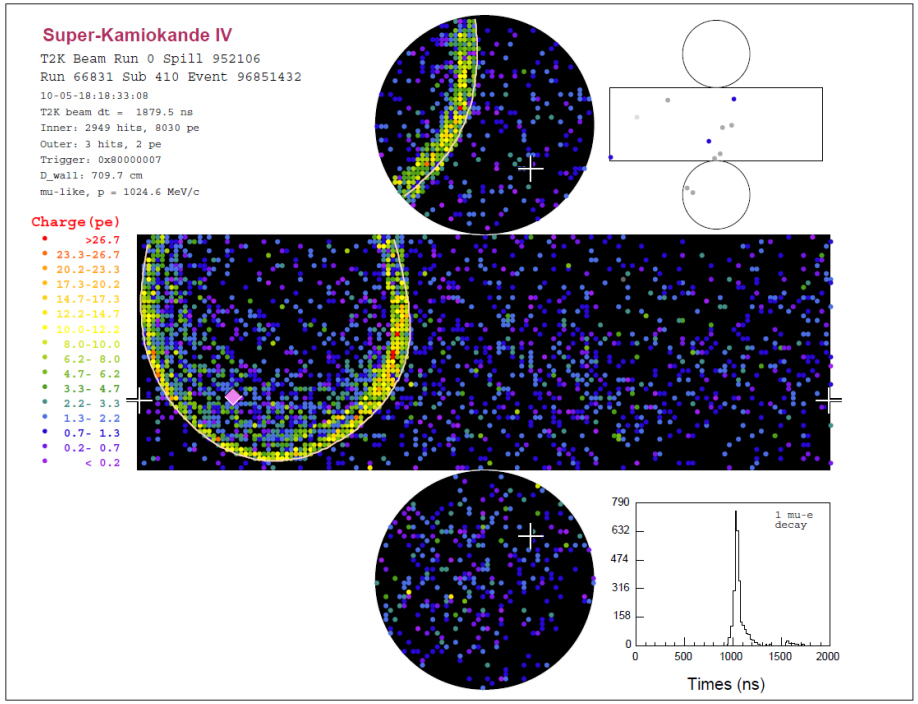
No off-bunch FC events.

RMS : 26nsec

→ GPS system is working correctly.

Event display
single-ring μ-like events





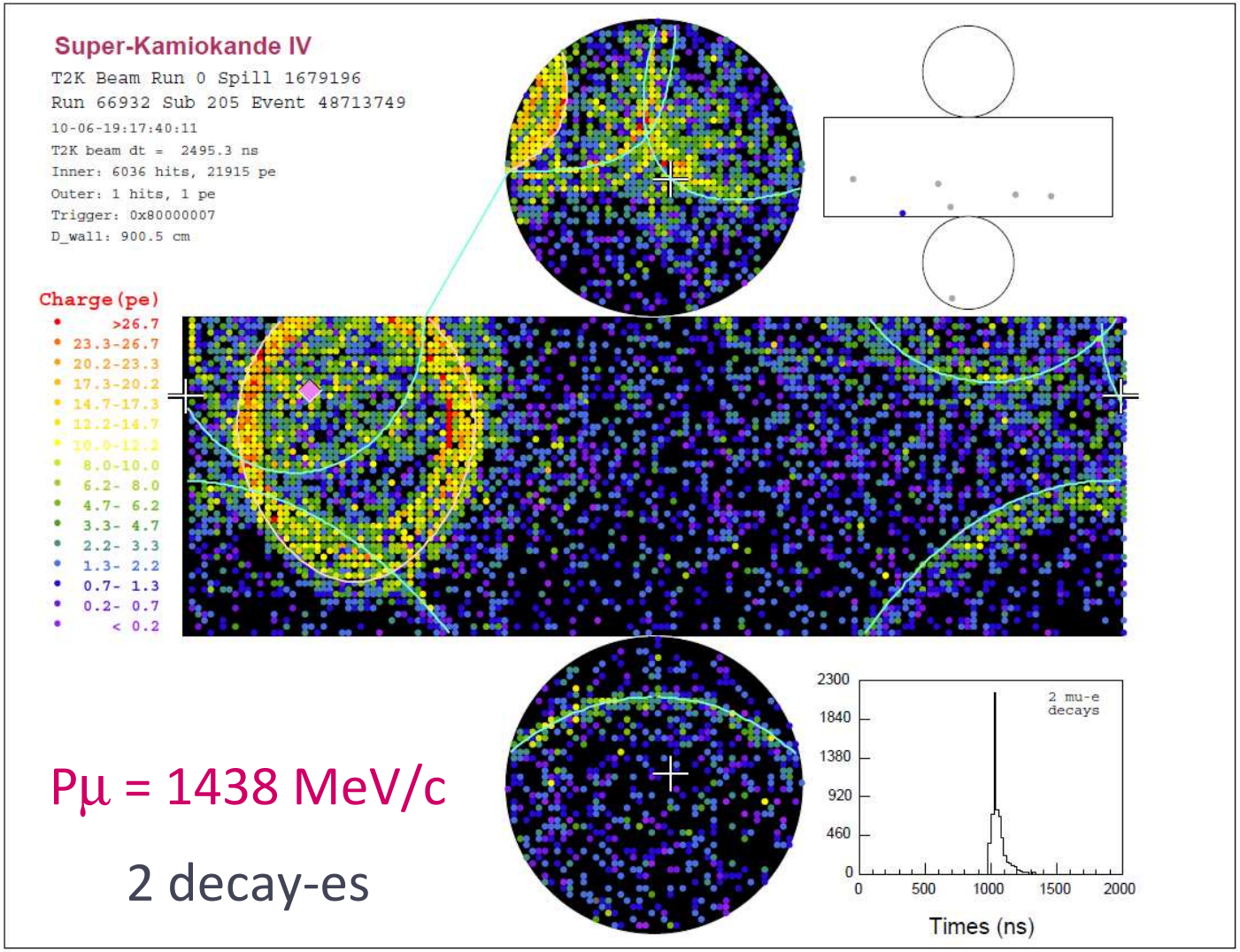
Pμ = 1061 MeV/c

1 decay-e

Pμ = 1025 MeV/c

1 decay-e

Event display
multi-ring μ-like event



Pμ = 1438 MeV/c

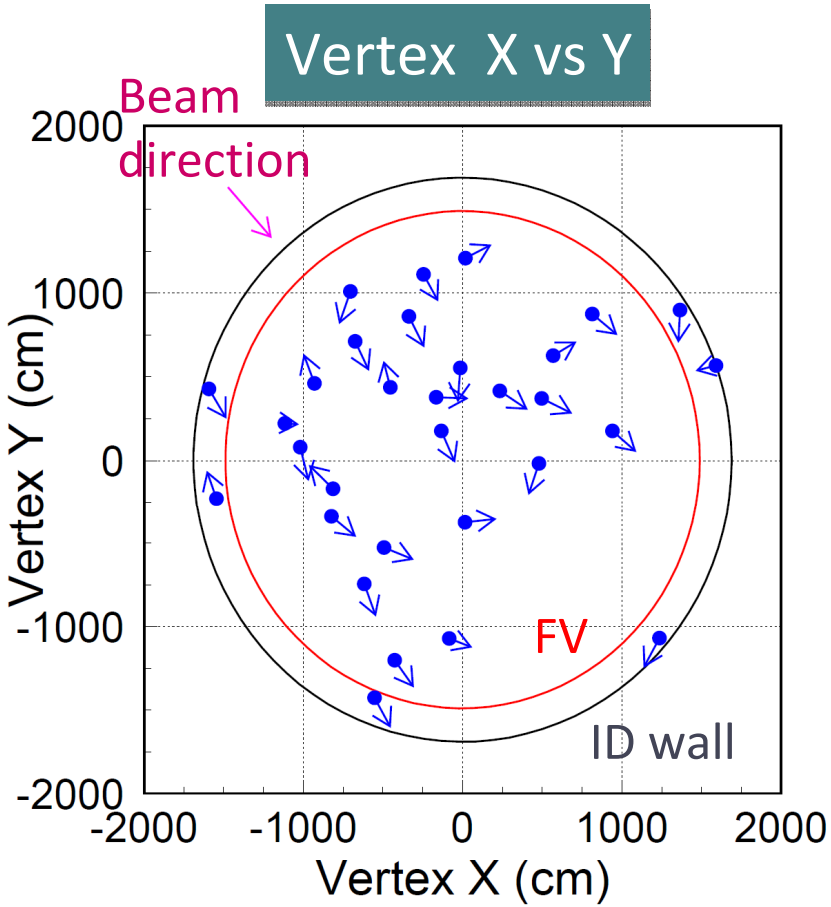
2 decay-es

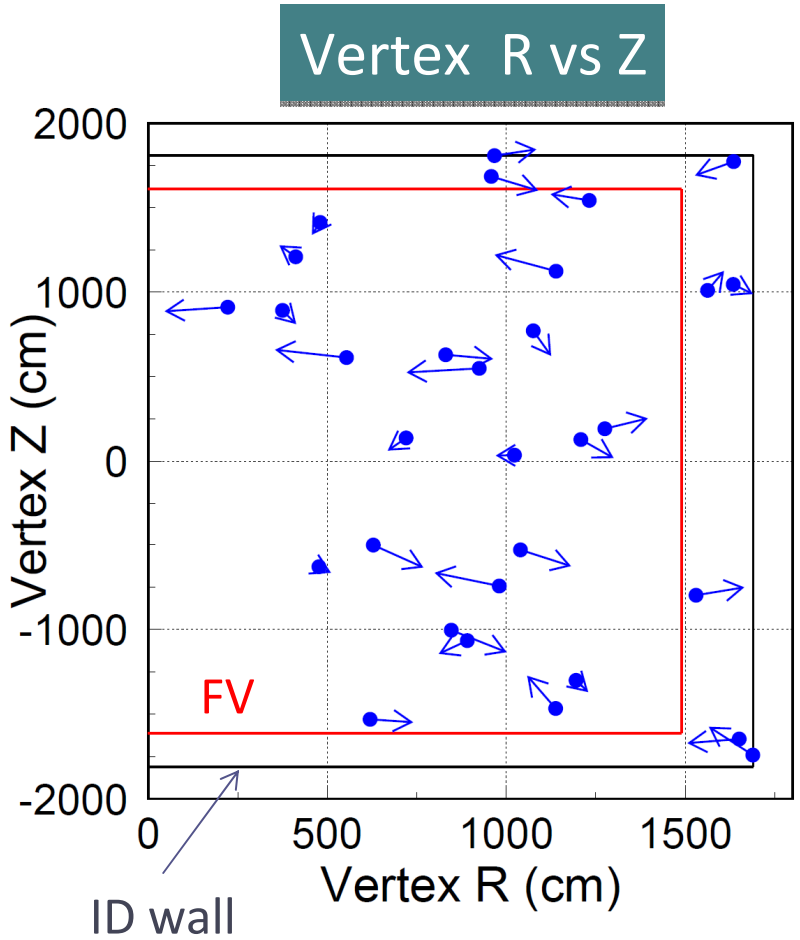
Vertex and direction

(FC, Evis>30MeV)

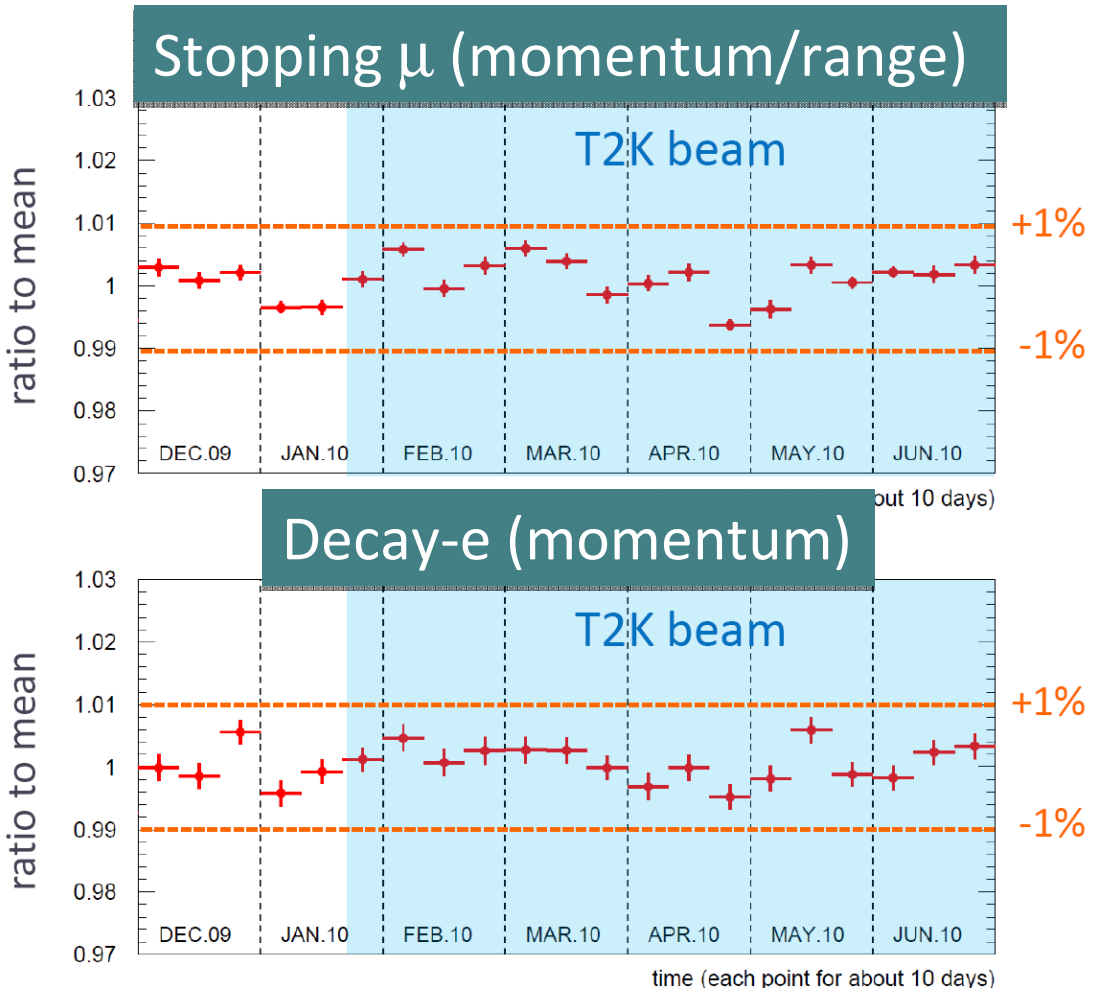
Points : Reconstructed event vertex

Arrow : 1st-ring direction





Super KamiokaNDE
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%)

Energy scale has been quite stable.

Conclusions

-- T2K experiment is now fully operational and data taking
-- superb detector performance
-- proton intensity increasing steadily
-- First data taking period in 2010 accumulated 3.23 10^{19} 30 GeV p.o.t.

-- Preparing first physics result for end 2010