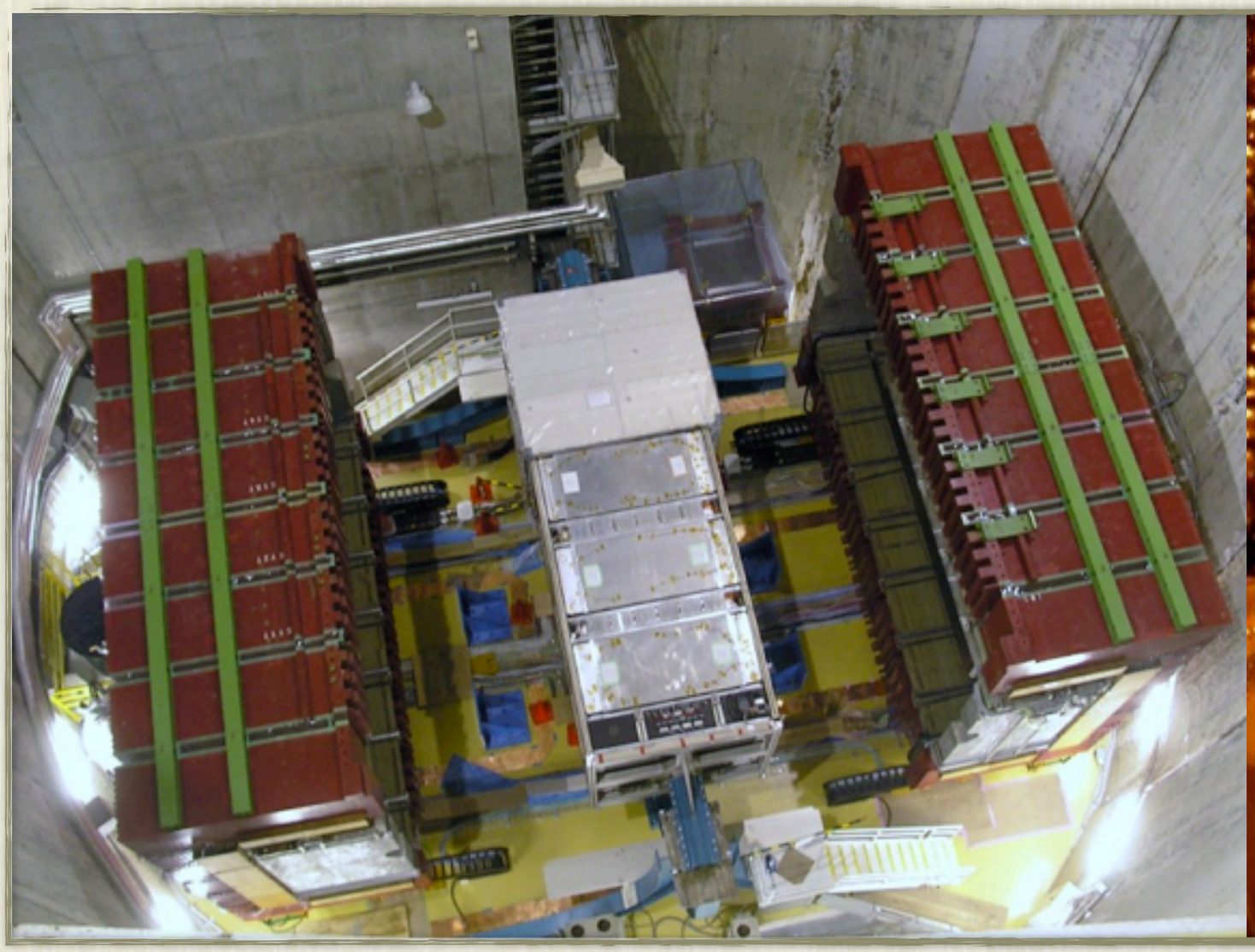
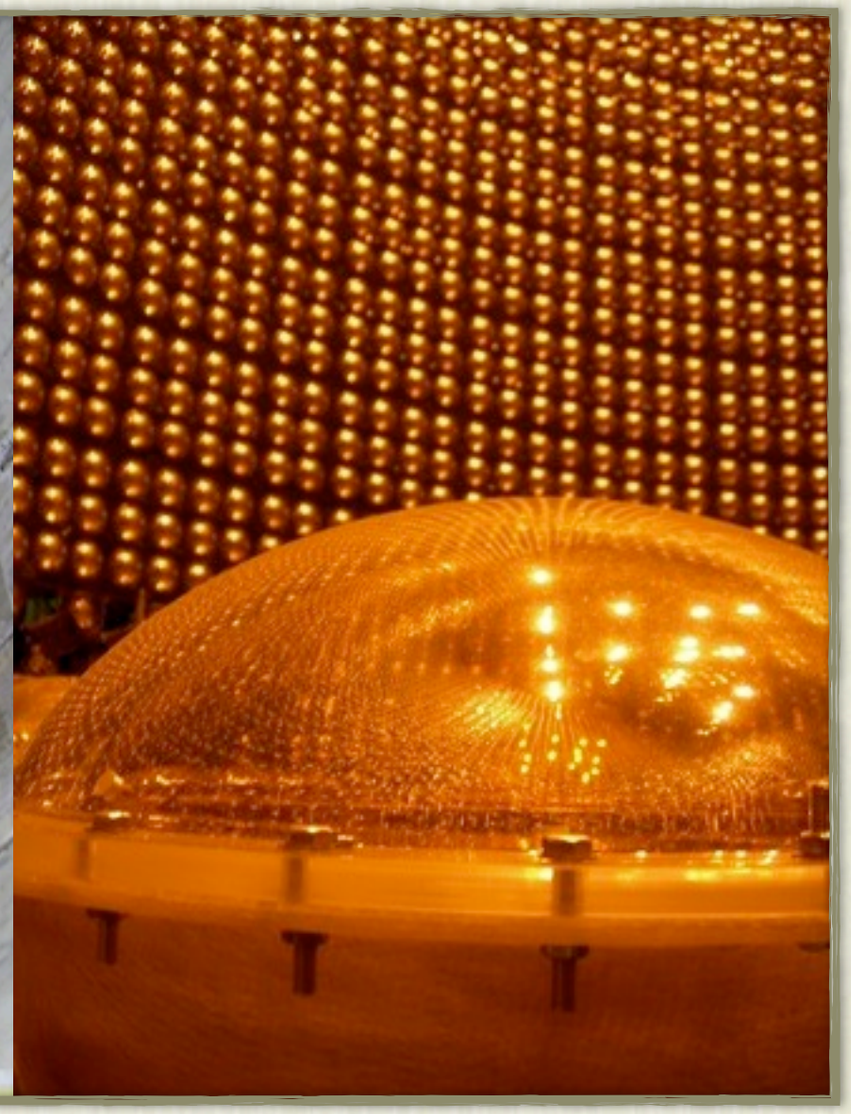
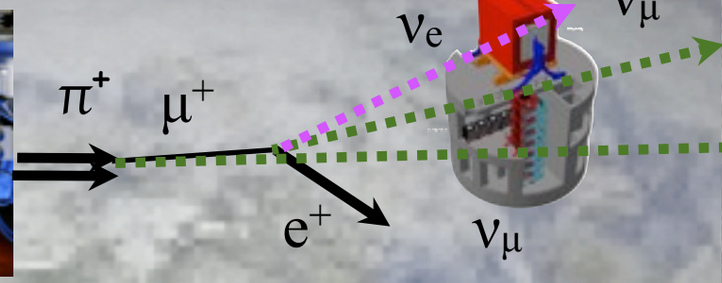


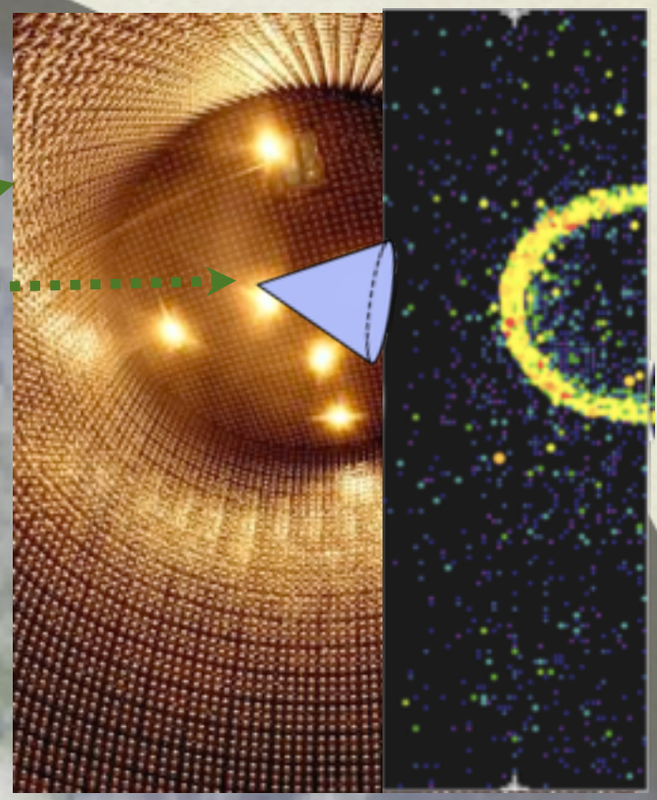


T2K Status

Fanny Dufour, Geneva University, for the T2K collaboration

Outline





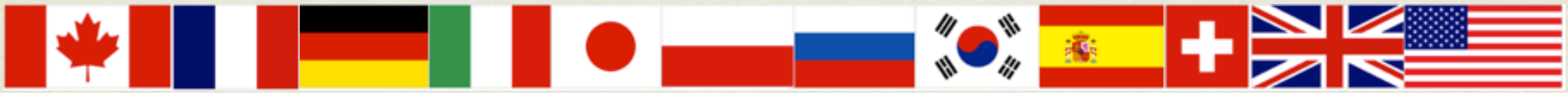
The T2K experiment

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

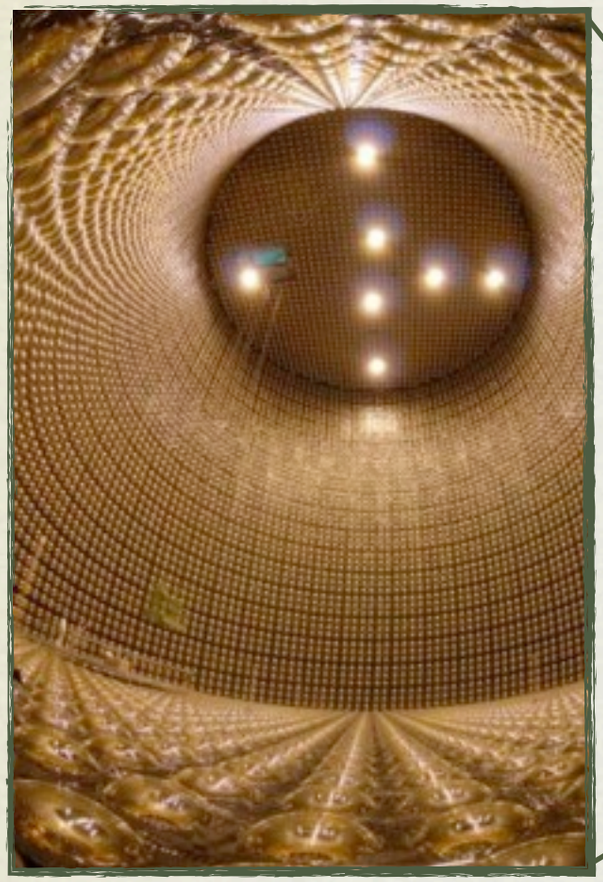
Spain
IFIC, Valencia
U. A. Barcelona

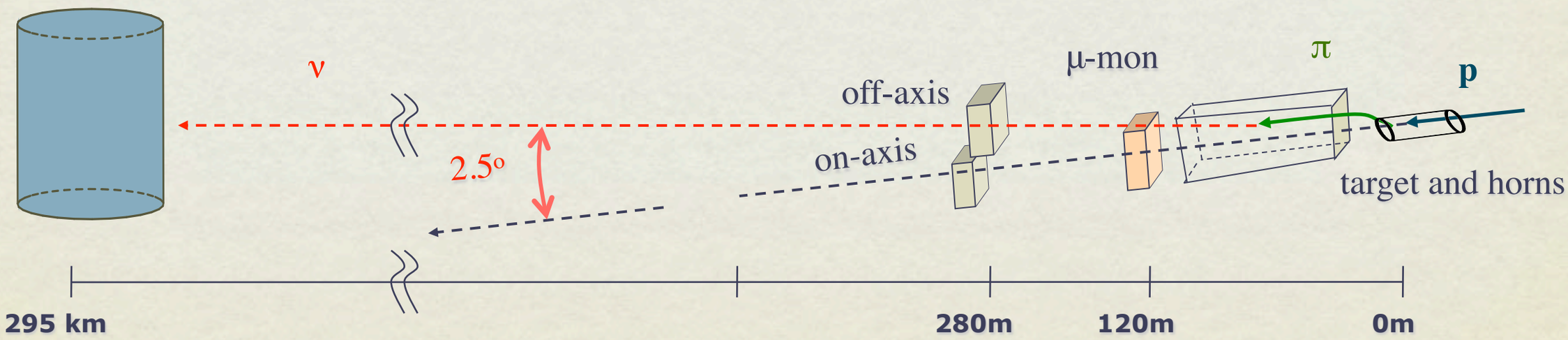
Switzerland
U. Bern
U. Geneva
ETH Zurich

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

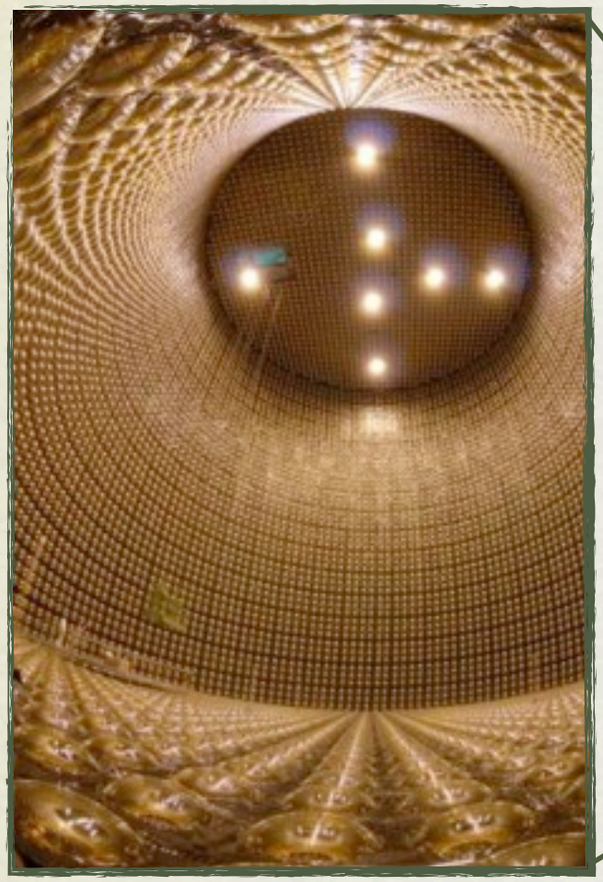
USA
Boston U.
B.N.L.
Colorado S. U.
Duke U.
Louisiana S. U.
Stony Brook U.
U. C. Irvine
U. Colorado
U. Pittsburgh
U. Rochester
U. Washington

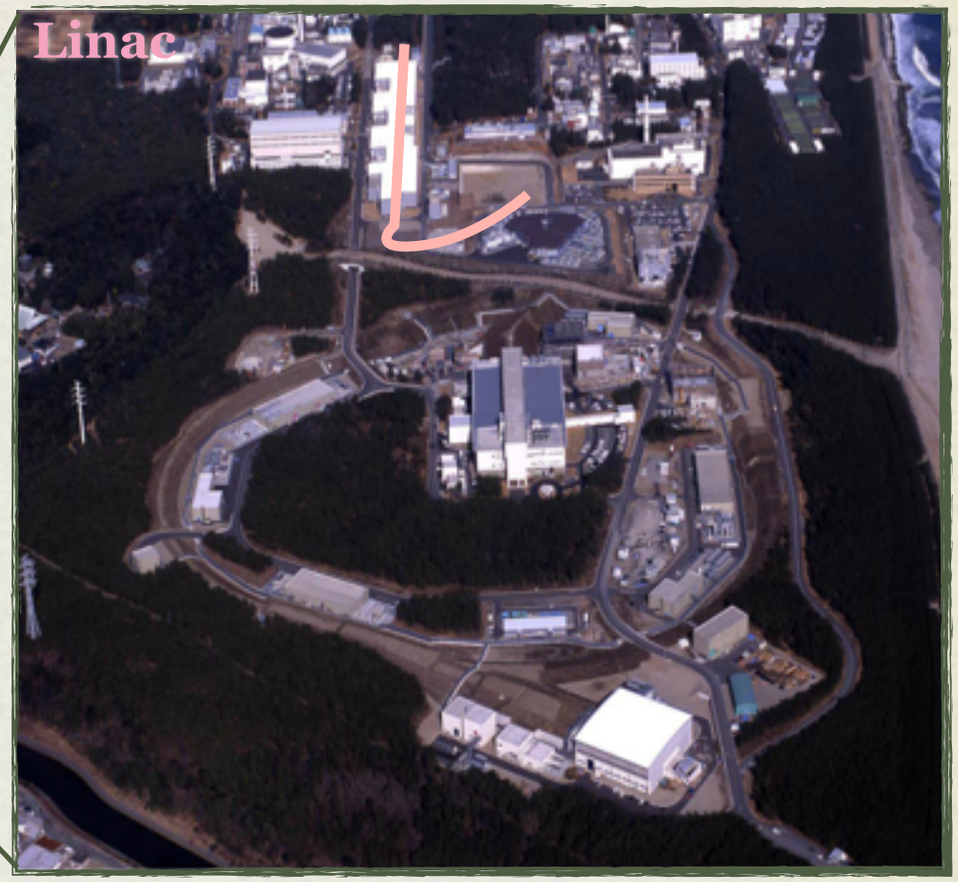
Overview of the experiment

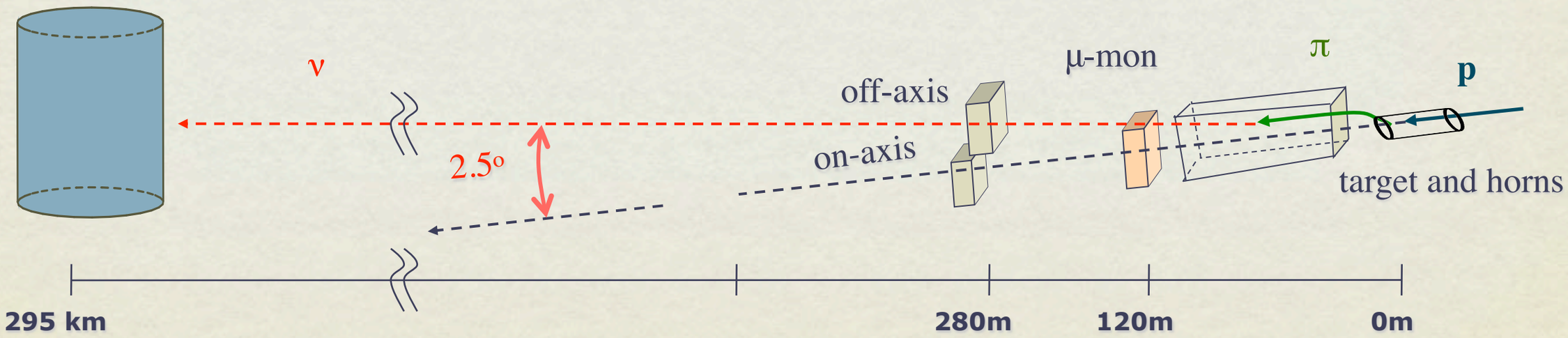




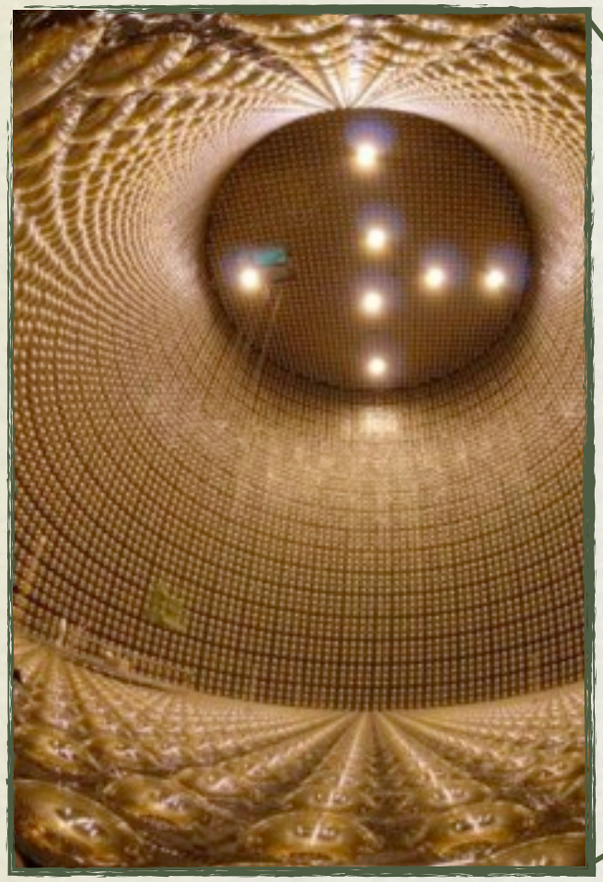
Overview of the experiment

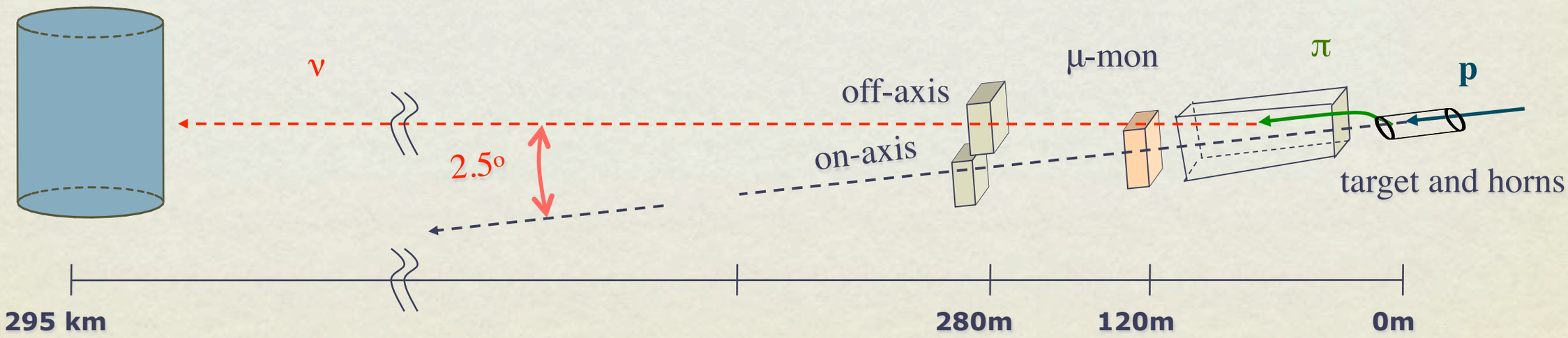




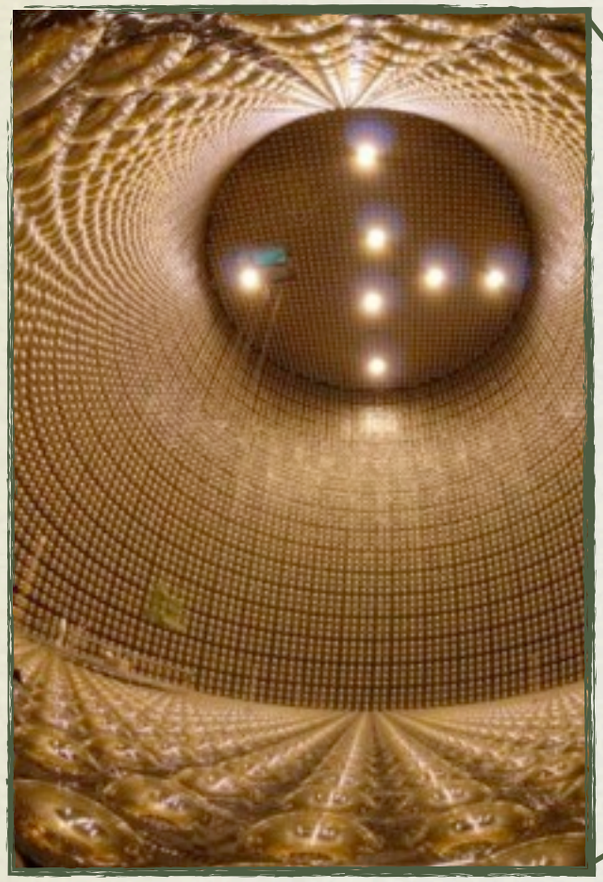


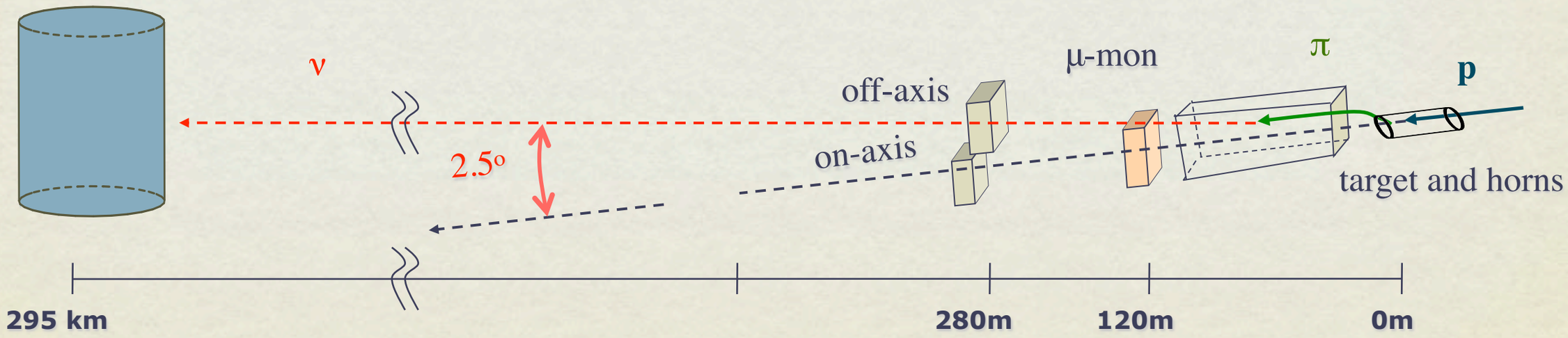
Overview of the experiment



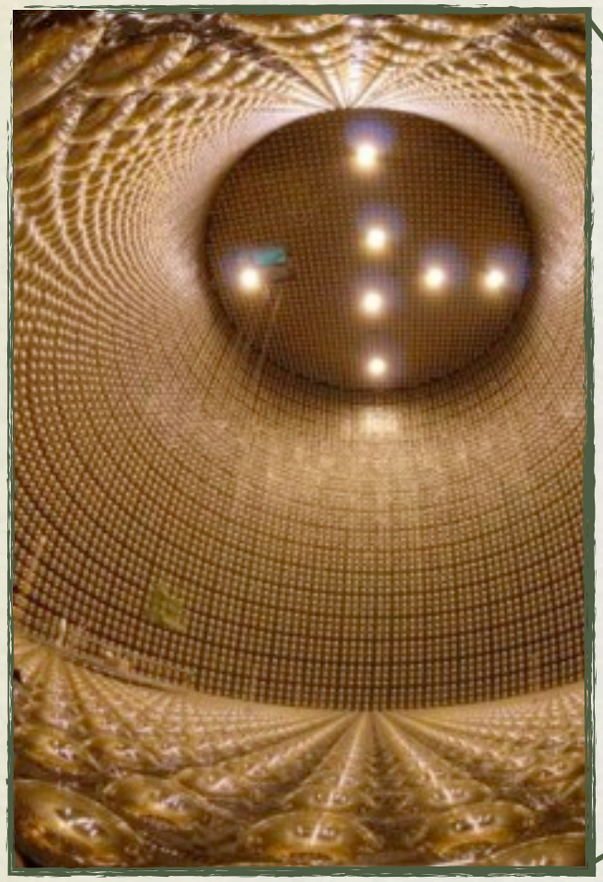


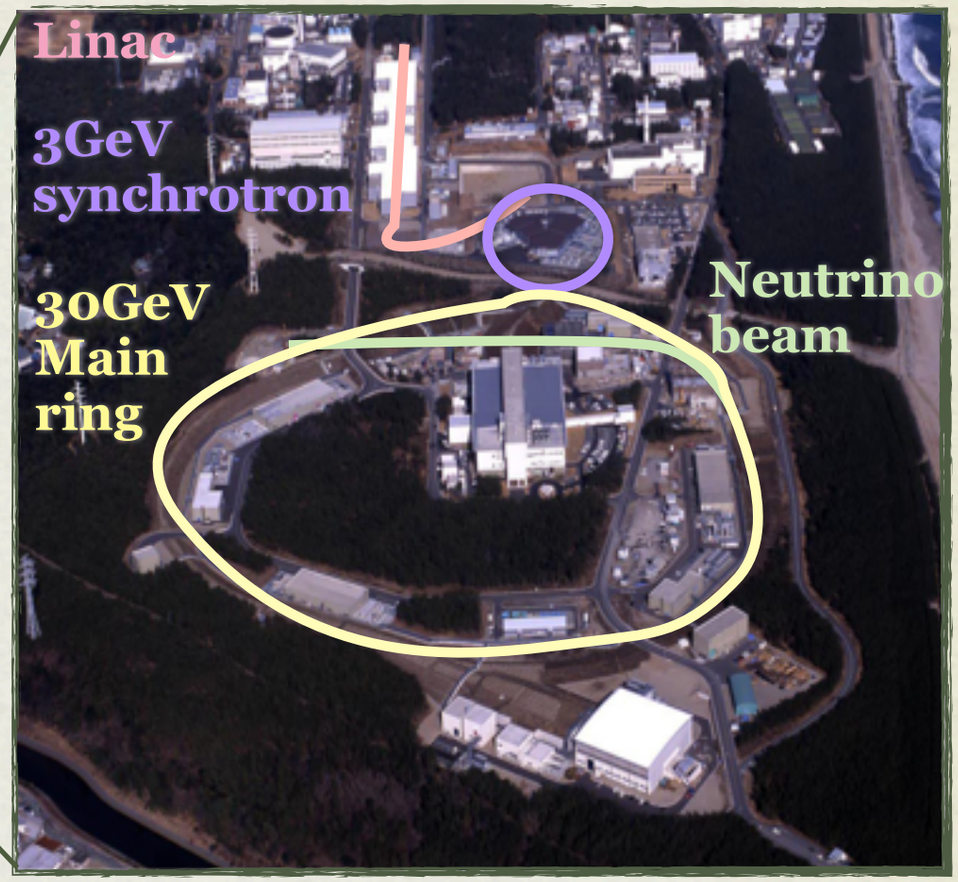
Overview of the experiment

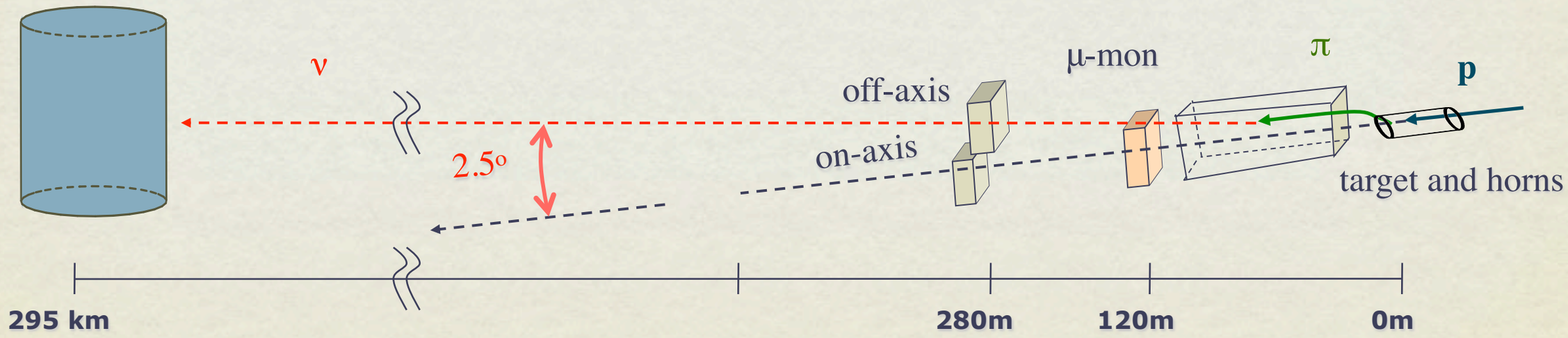




Overview of the experiment







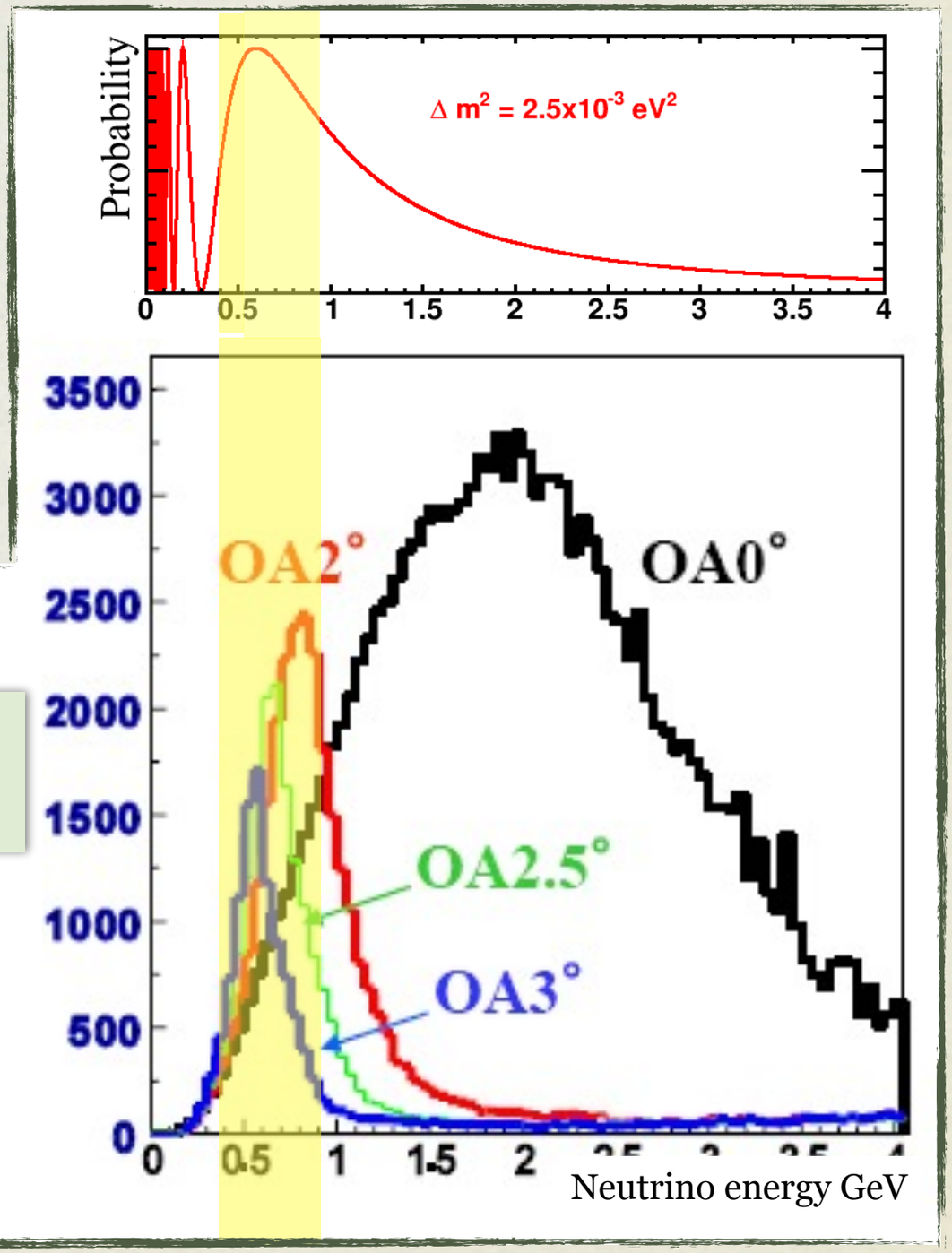
Off-axis principle

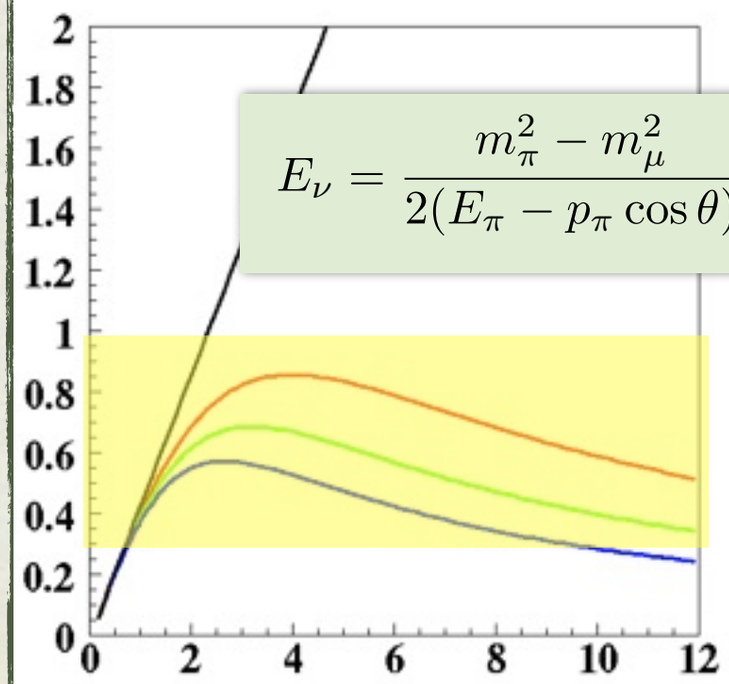
Detector is 2.5° off-axis

→ Narrow beam

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

→ Reduced background from non quasi-elastic and neutral current background



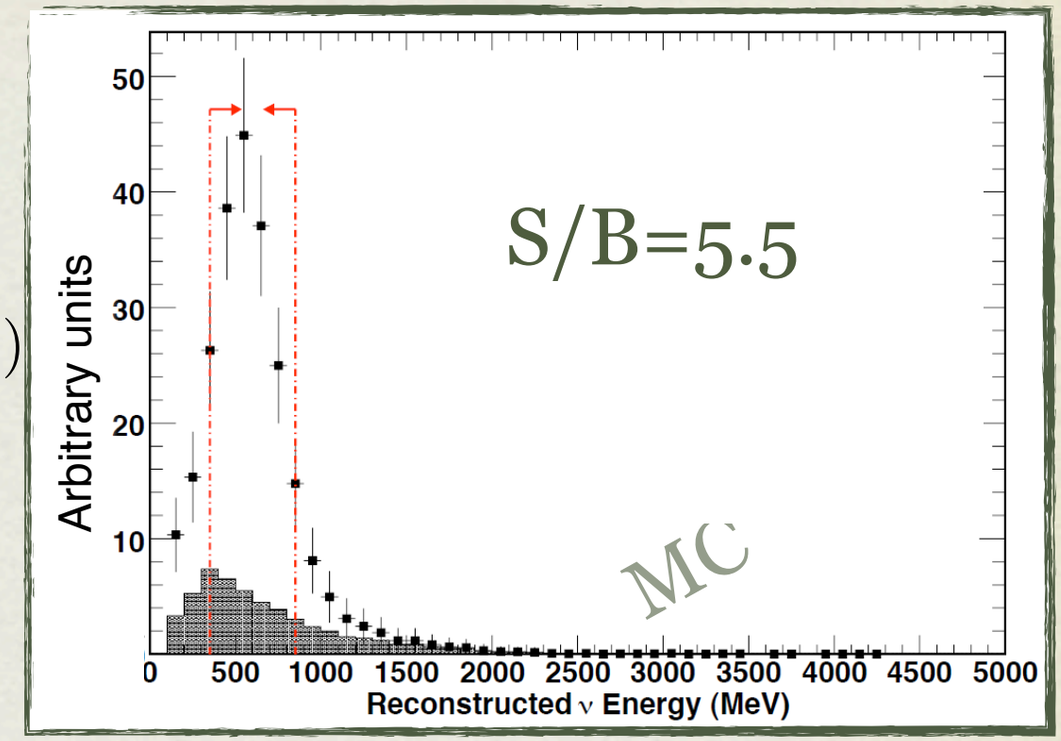


$$E_\nu = \frac{m_\pi^2 - m_\mu^2}{2(E_\pi - p_\pi \cos\theta)}$$

Physics goals (1): Neutrino oscillations

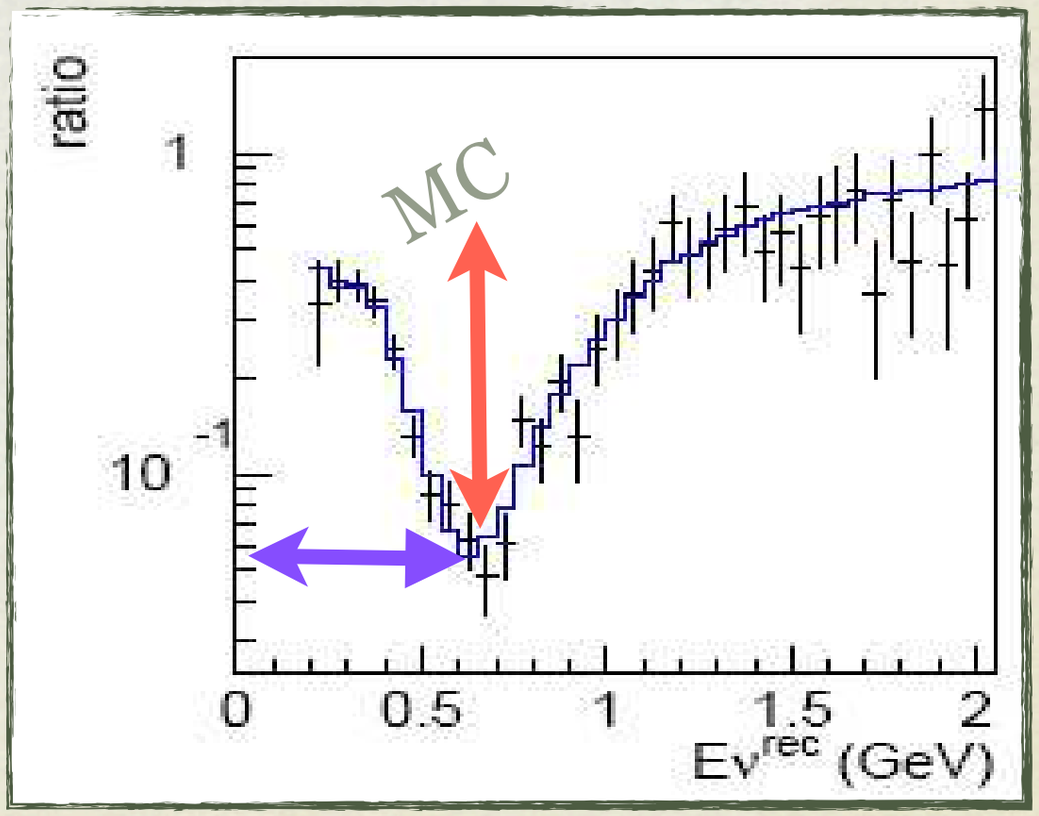
Appearance measurement: $\nu_\mu \rightarrow \nu_e$

$$P(\nu_\mu \rightarrow \nu_e) \approx \left(\sin^2(2\theta_{23}) \sin^2(2\theta_{13}) \right) \sin^2\left(\frac{\Delta m^2_{23} L}{4E}\right)$$

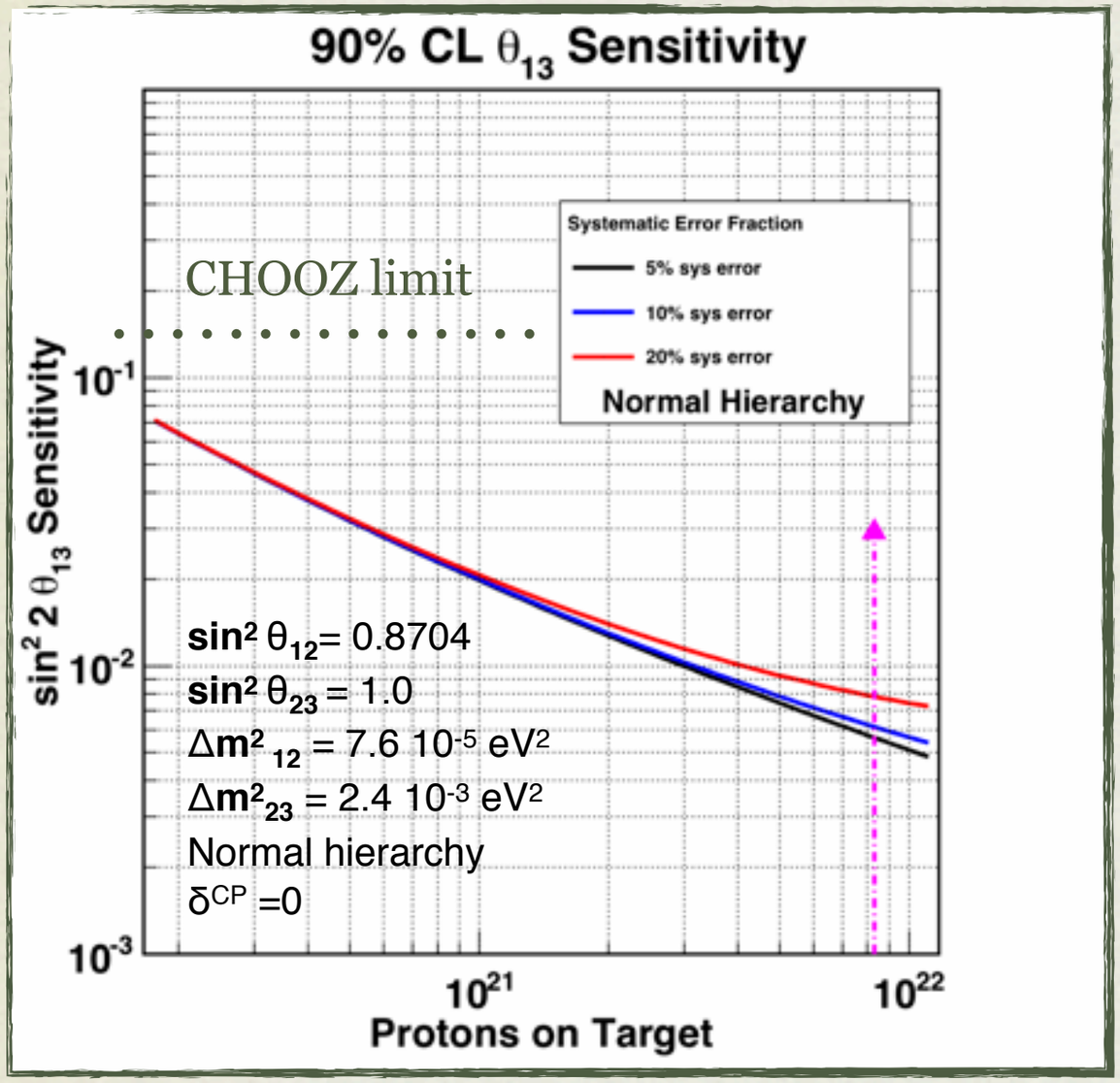


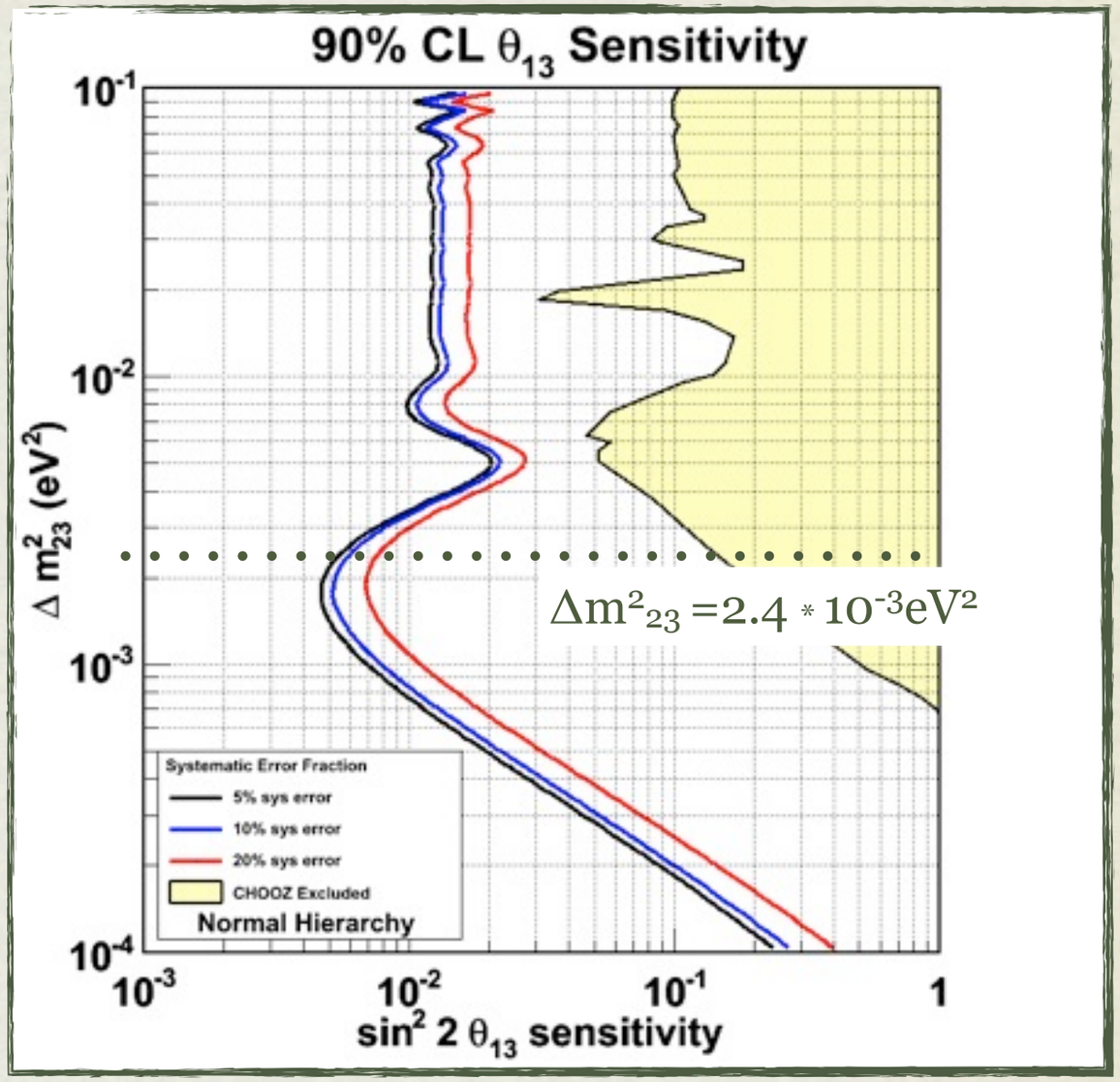
Disappearance measurement: $\nu_\mu \rightarrow \nu_\mu$

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



Sensitivity to θ_{13}





90% C.L.:
750 kW X ($5 * 10^7$ sec)
→ 8.3 x 10^{21} POT
with 22.5 kton fiducial volume

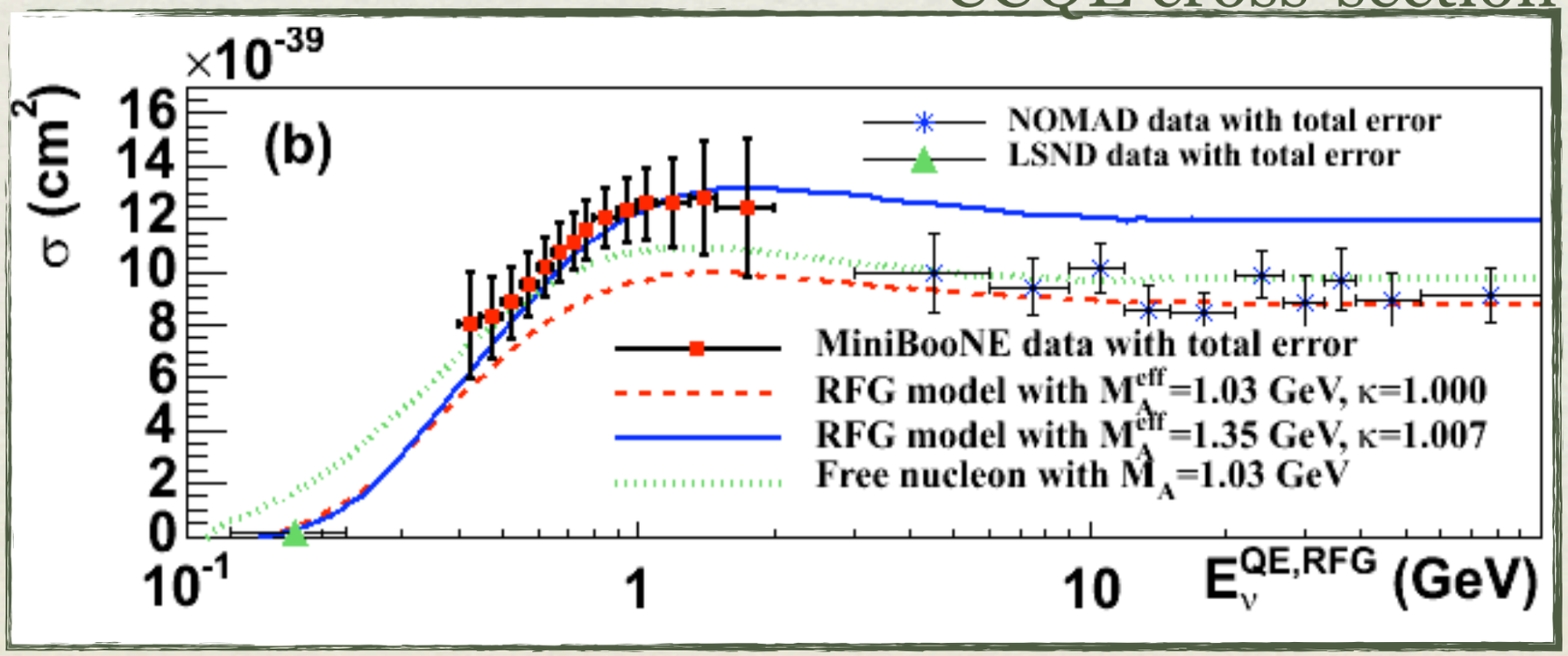
Physics goals (2): Cross-section measurements

Recent measurements from MiniBoone do not agree with previous measurements from NOMAD.

Measurements of cross-section in the low energy region will be beneficial to the entire neutrino community.

The off-axis near detector will be able to do such measurements

CCQE cross-section



T. Katori Nuint09, Elba10

Overall analysis strategy

$$N(E_\nu^{rec}) = \Phi_{SK}^{exp}(E_\nu^{true}) \times \sigma(E_\nu^{true}) \times P_{osc}(E_\nu^{true}) \times \epsilon_{SK}(E_\nu^{true}) \times f(E_\nu^{rec}, E_\nu^{true})$$

Number of reconstructed events (ν_μ and ν_e) at SK can be predicted using
near detectors (off-axis beam, neutrino cross sections)
hadron production measurements (NA-61)
Compare prediction with SK observation to extract oscillation parameters :

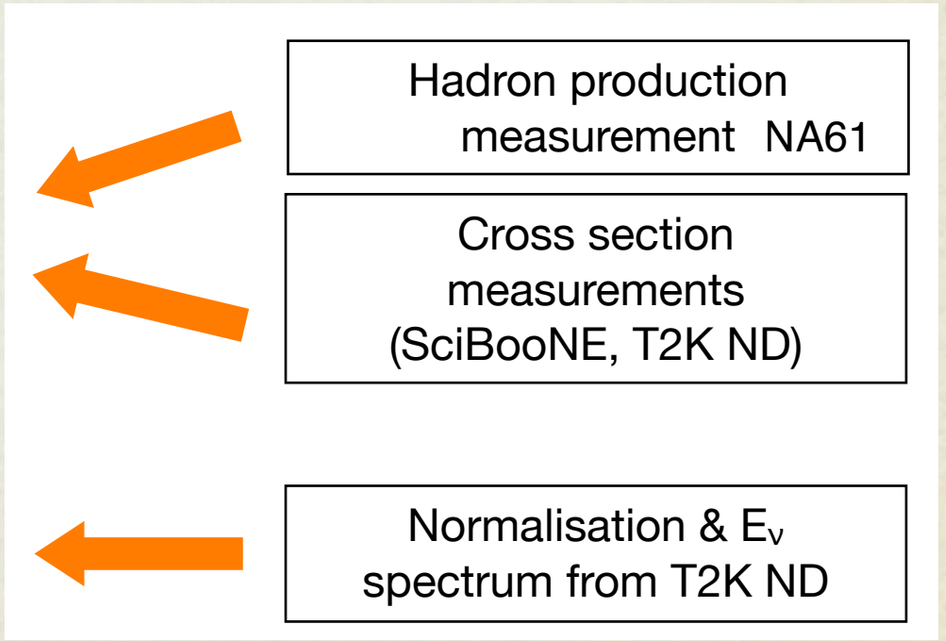
Near detector flux

$$\Phi_{ND} = N_{ND}^{obs}/(\sigma_{ND} \times \epsilon_{ND})$$

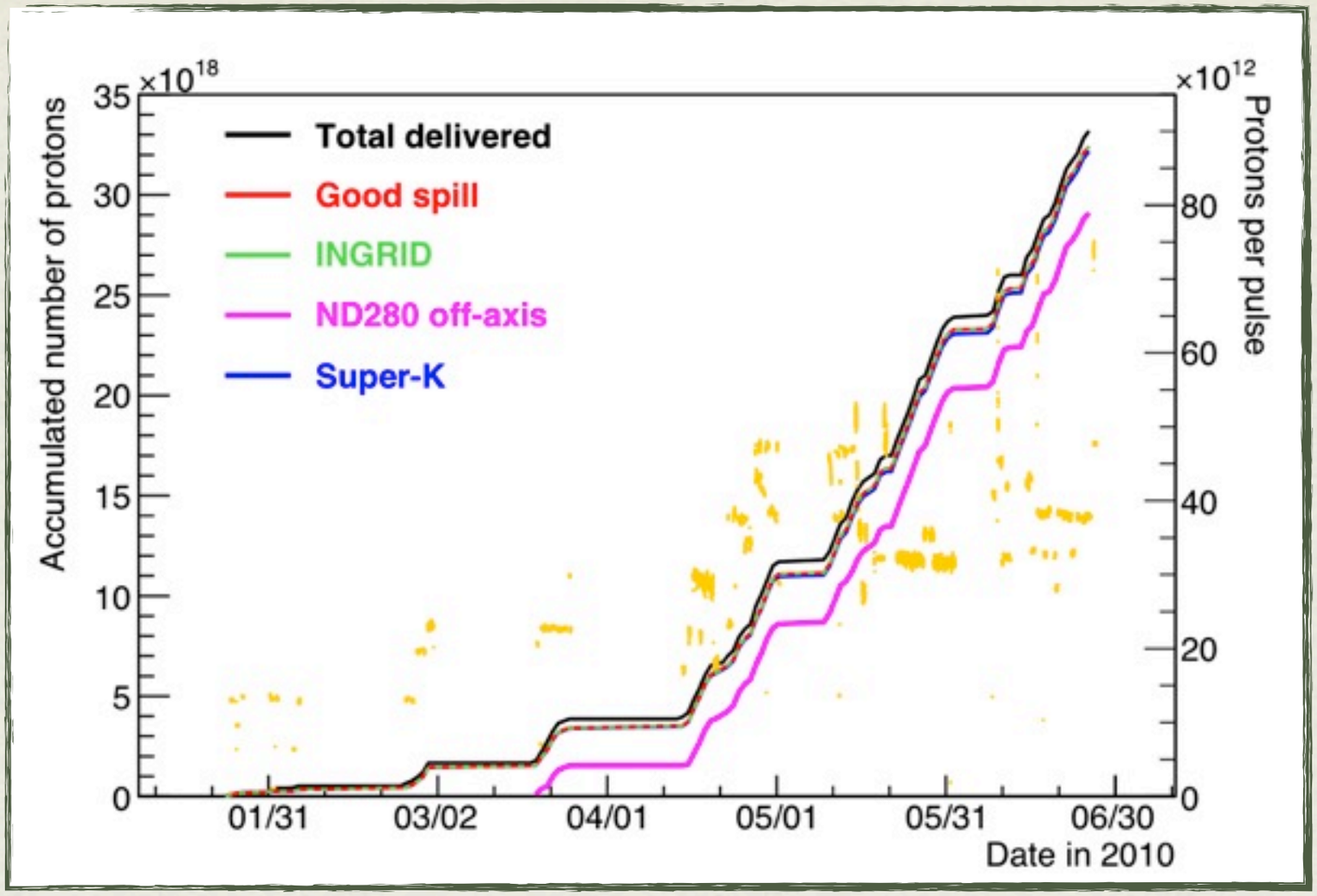
Far to near extrapolation factor

Flux at SK

$$\Phi_{SK} = R_{SK/ND} \times \Phi_{ND}$$



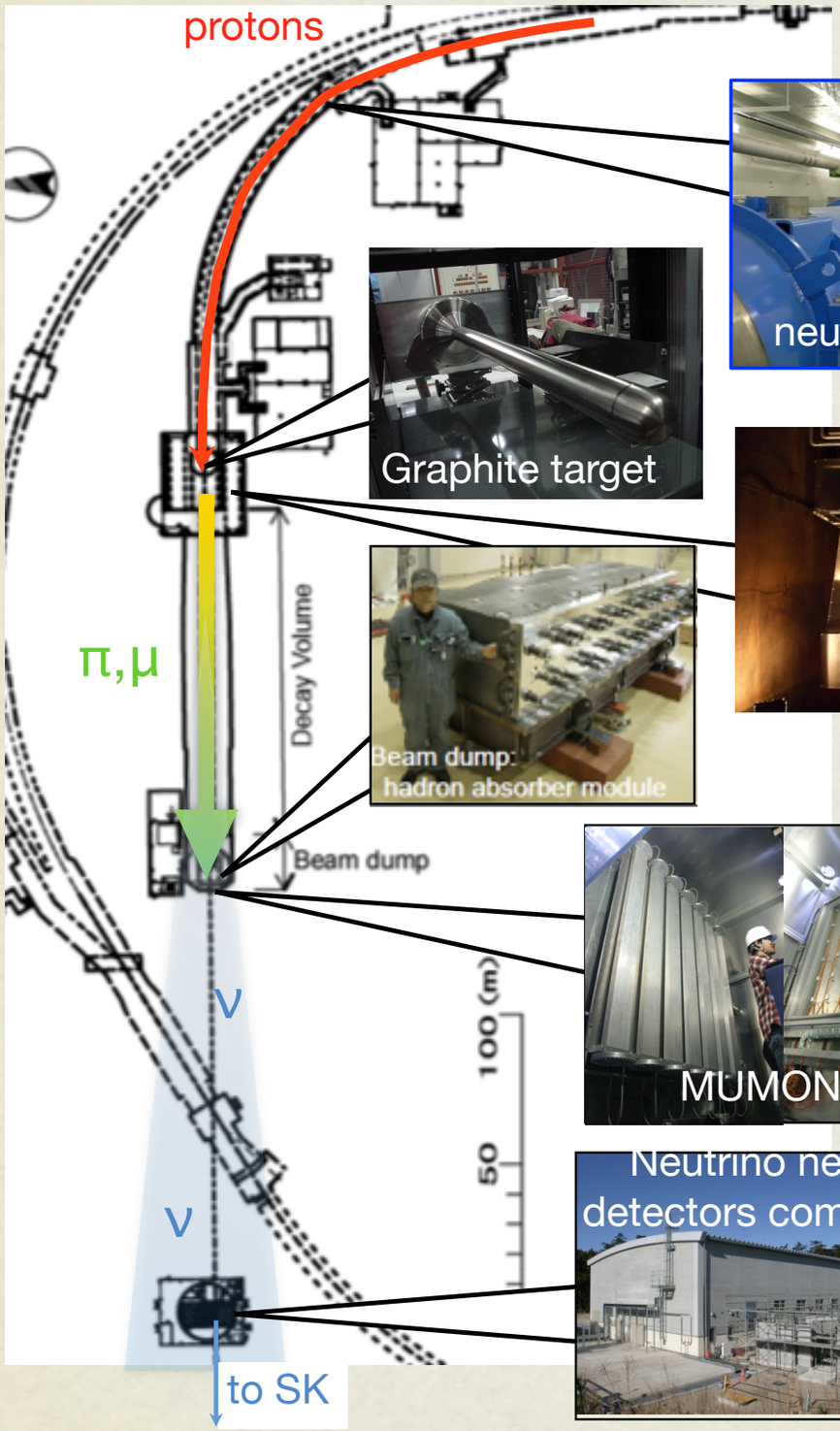
Proton on target collected in 2010

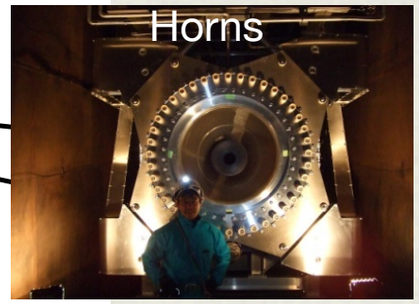


First T2K run completed (January to June 2010)

- 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 $\times 10^7$ sec by July 2011

Beamline overview





Fast extracted beam from MR ring

- 6 bunches/spill (increased to 8 in Fall 2010)
- Superconducting combined function magnets for proton transport

Primary beam monitors

- Intensity(CT), position(ESM), profile(SSEM), beam loss(IC), beam profile at target (OTR)

Target Station

- graphite core target (26 mm(D) x 900 mm L)
- 3 horns @ 250 kA (320 kA)

Target station connected to decay pipe 110 m long filled with Helium

Beam dump

- Hadron absorber graphite modules

Secondary beam monitors

- muon profile after beam dump : ionisation chambers and SiPIN (MUMON)
- Emulsion exposures (low intensity)

Neutrino detectors at 280 m

Super-K direction given by GPS

Antonin Vacheret, NOW 2010

ND280 overview

On-axis detector:

INGRID

Off-axis detector:

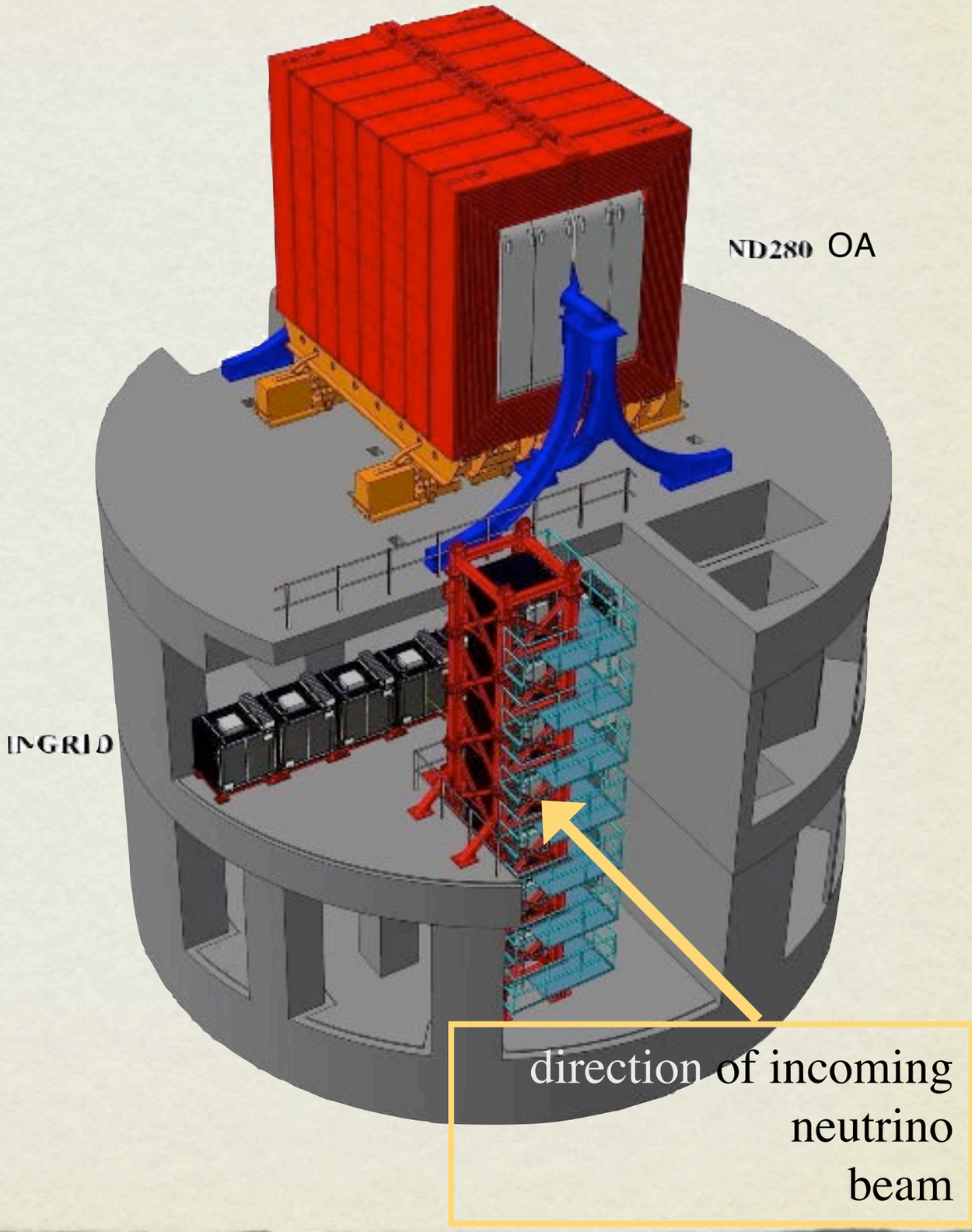
sits inside the old UA1/NOMAD magnet

tracker: FGD +TPC

P0D

ECAL (downstream and barrel)

SMRD

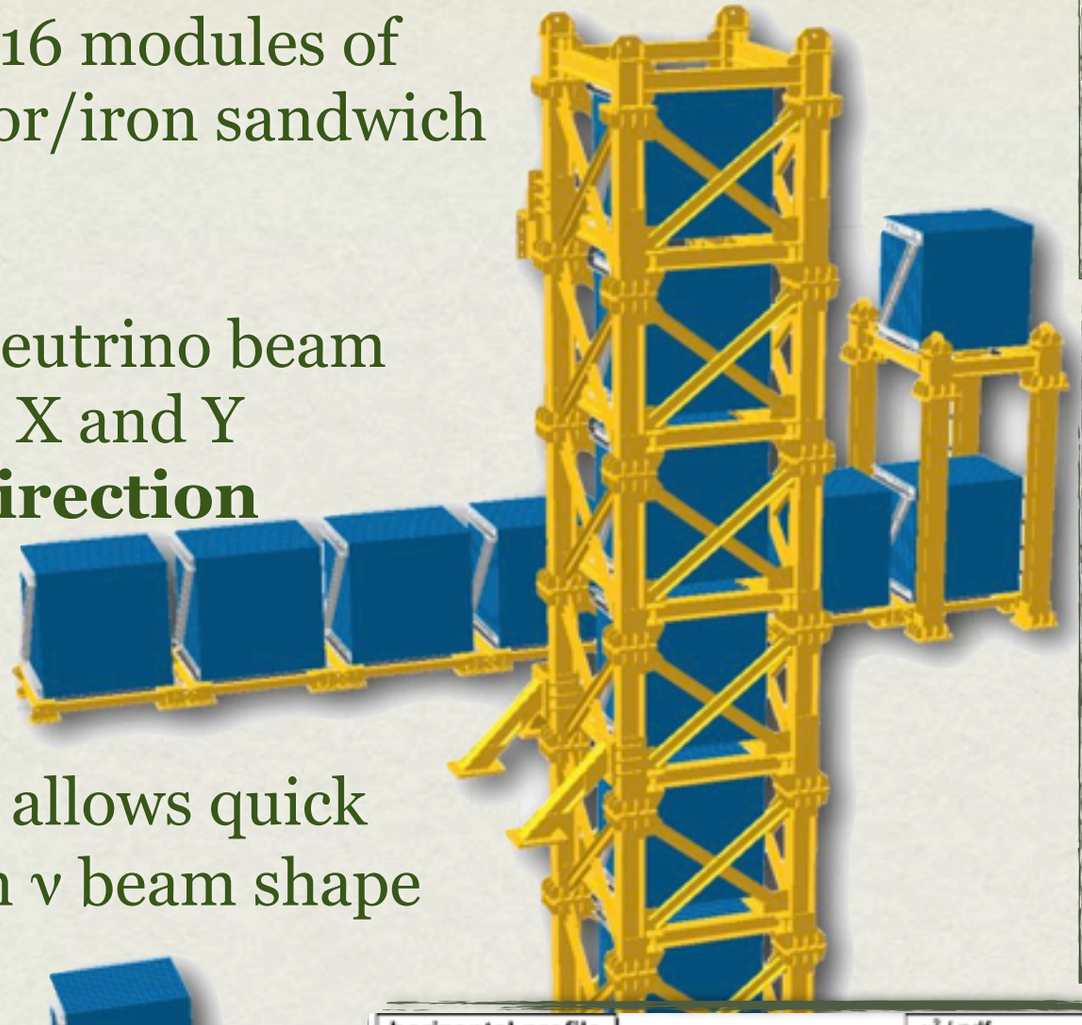


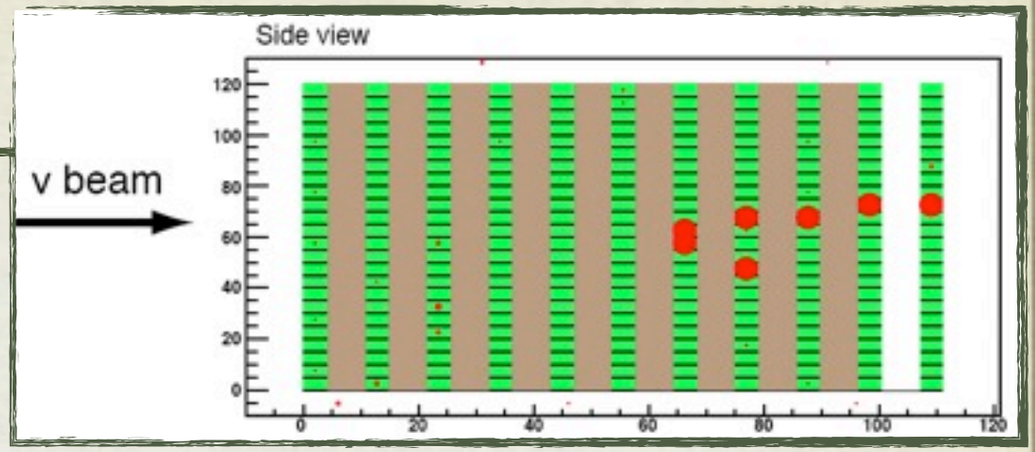
ND280 on-axis detector: INGRID

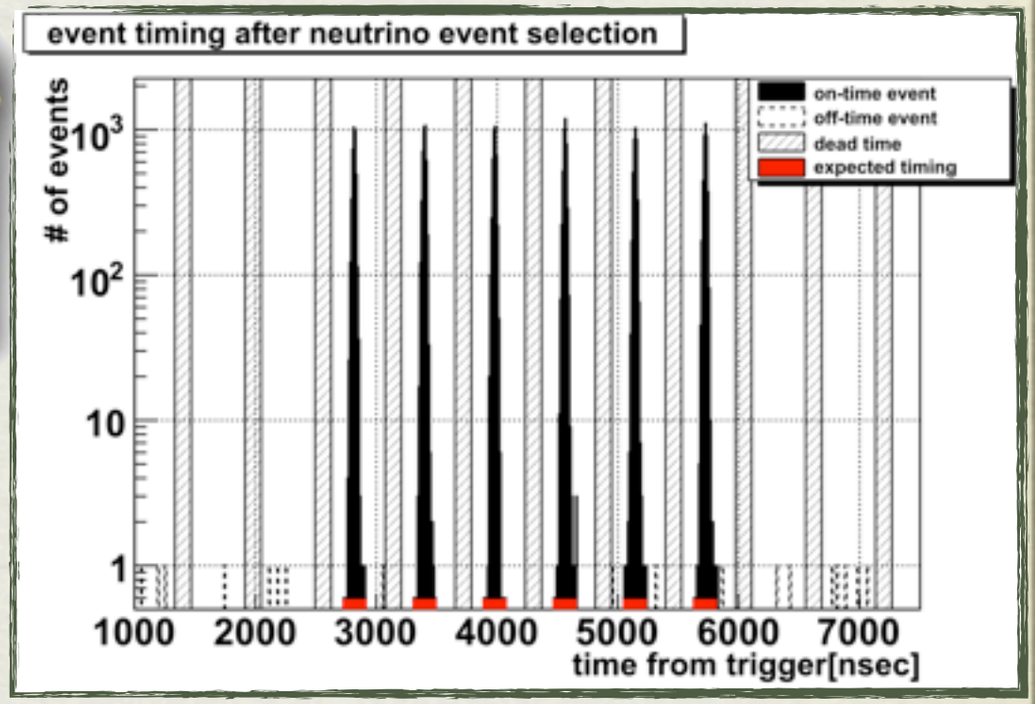
Consists of 16 modules of scintillator/iron sandwich planes

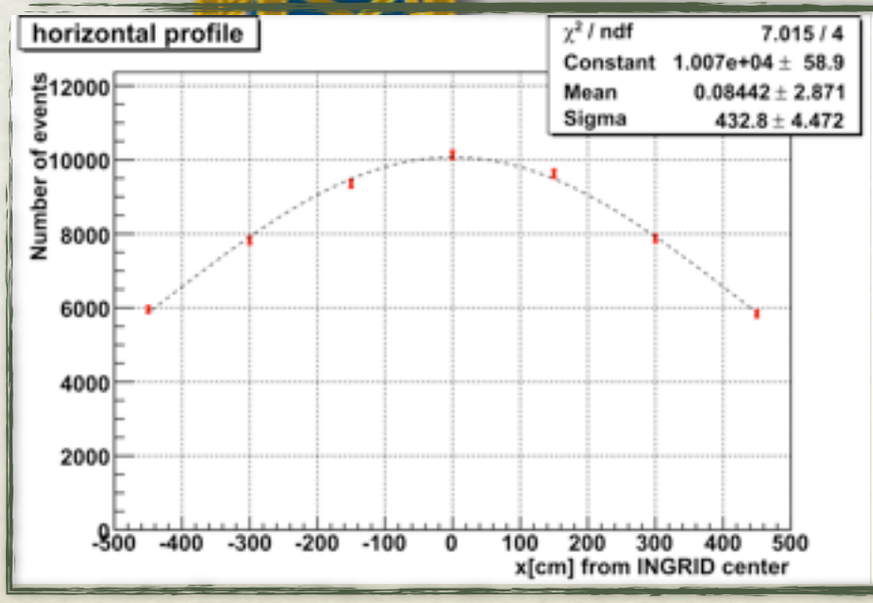
Measures neutrino beam profile in X and Y
→ **beam direction**

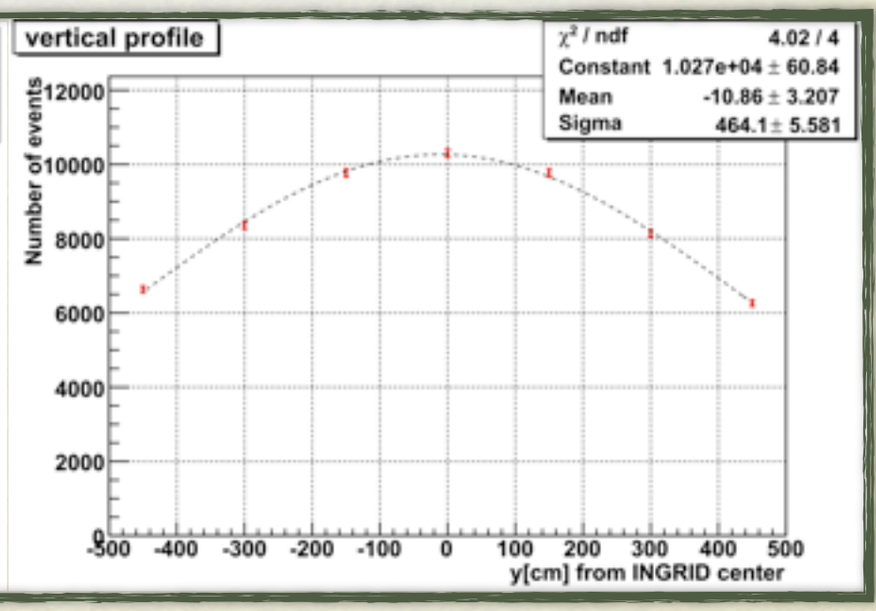
Large mass allows quick feedback on ν beam shape



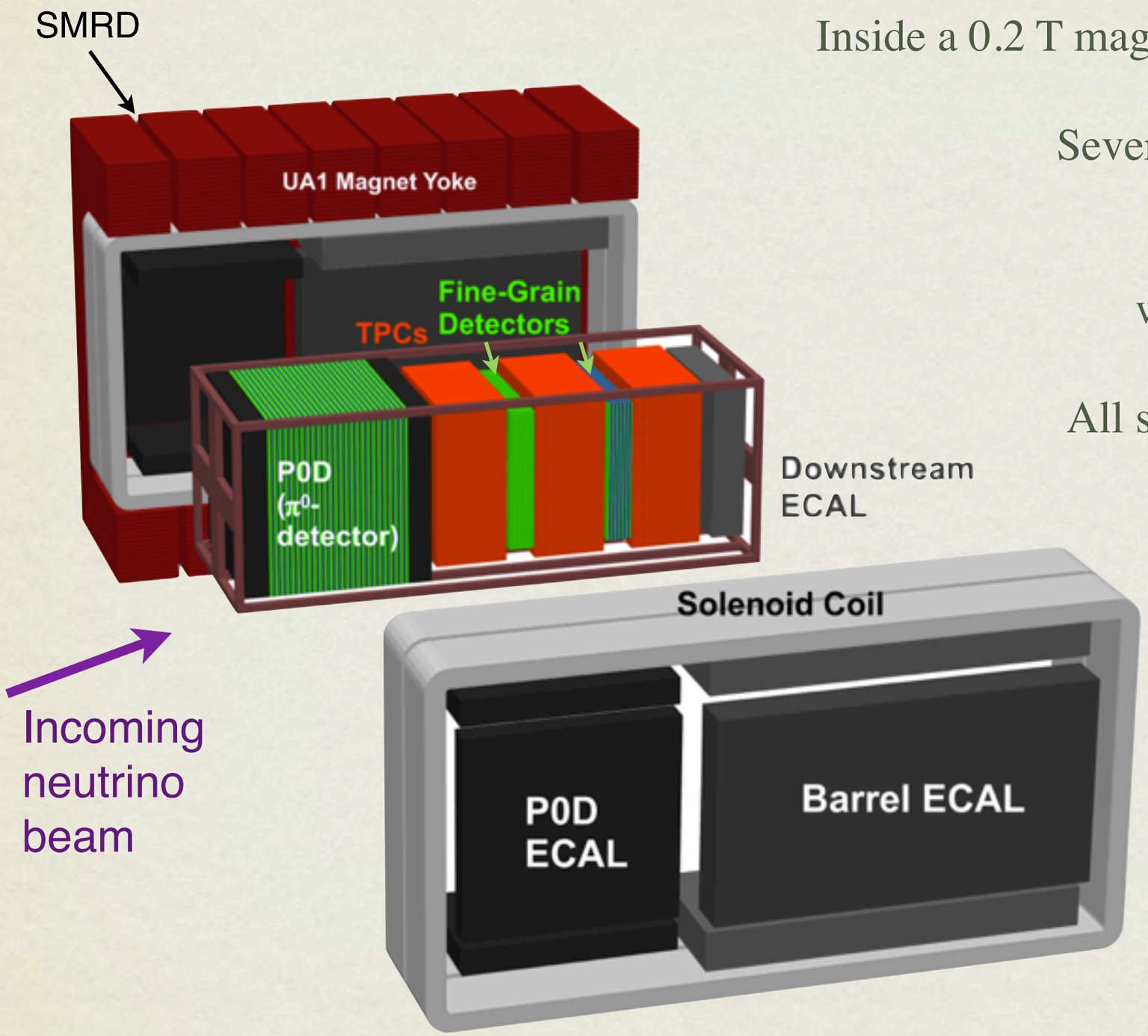








ND280 off-axis detector



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 which was installed in summer 2010

Purpose

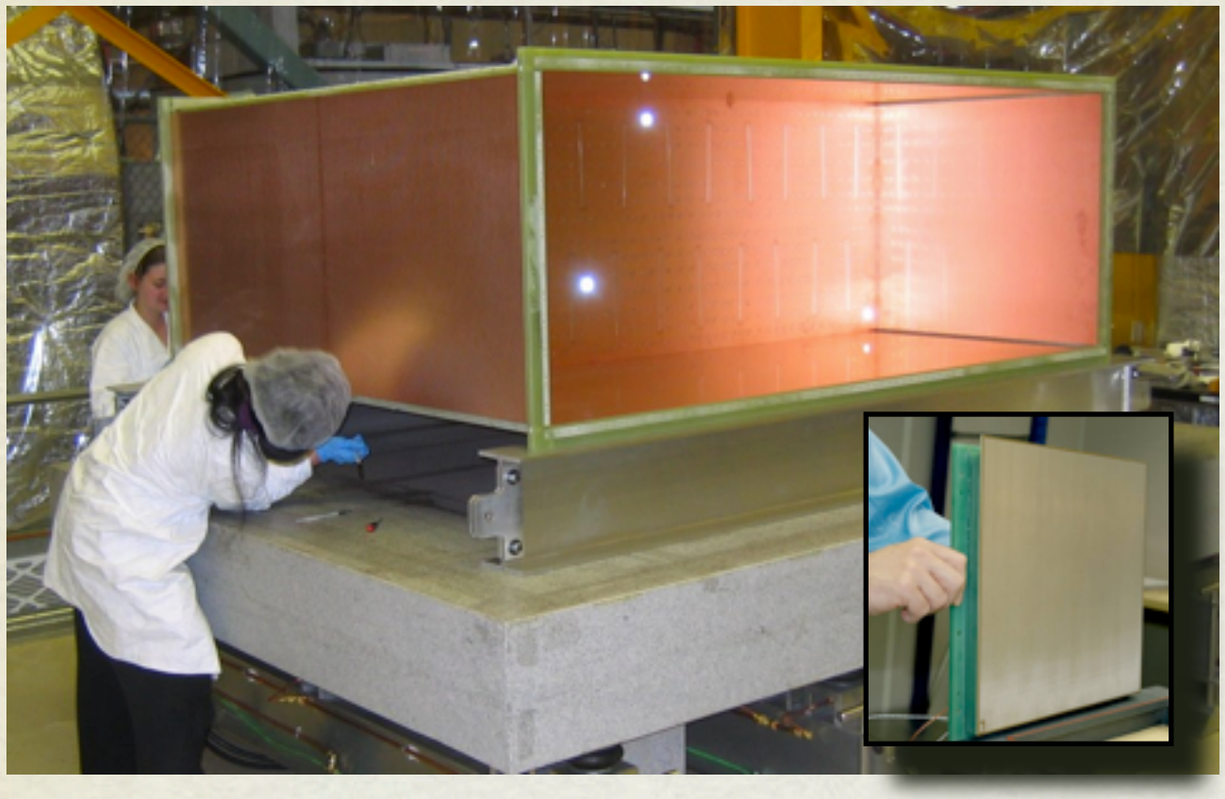
CC ν_μ events (normalization, disappearance)

CC ν_e events

π^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

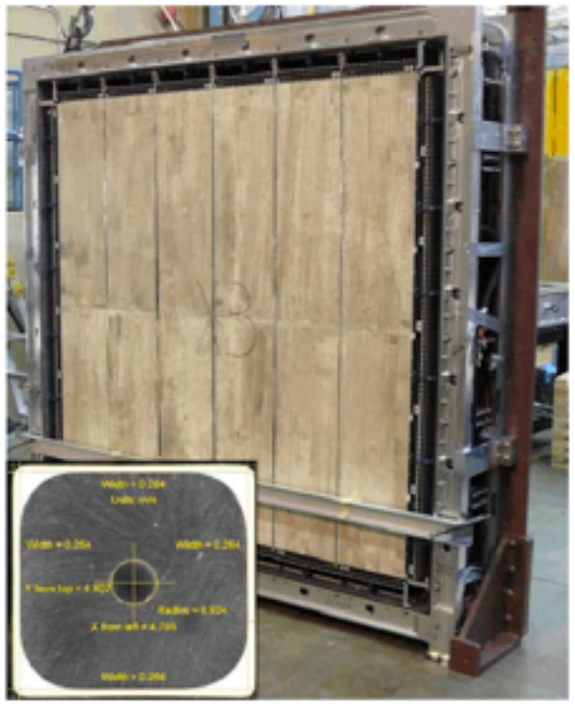
<u>2 Fine Grained Detectors (FGD)</u>

2 x1.3 Ton active target

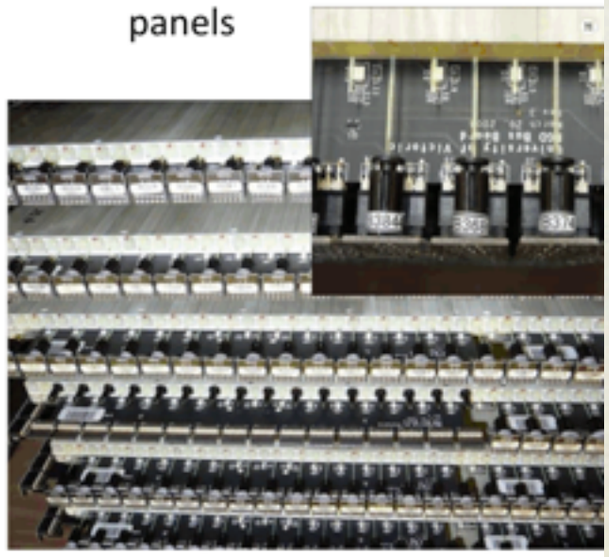
FGD1: plastic only FGD2: Plastic + water

Light detection by Geiger mode avalanche photodiodes (MPPC)

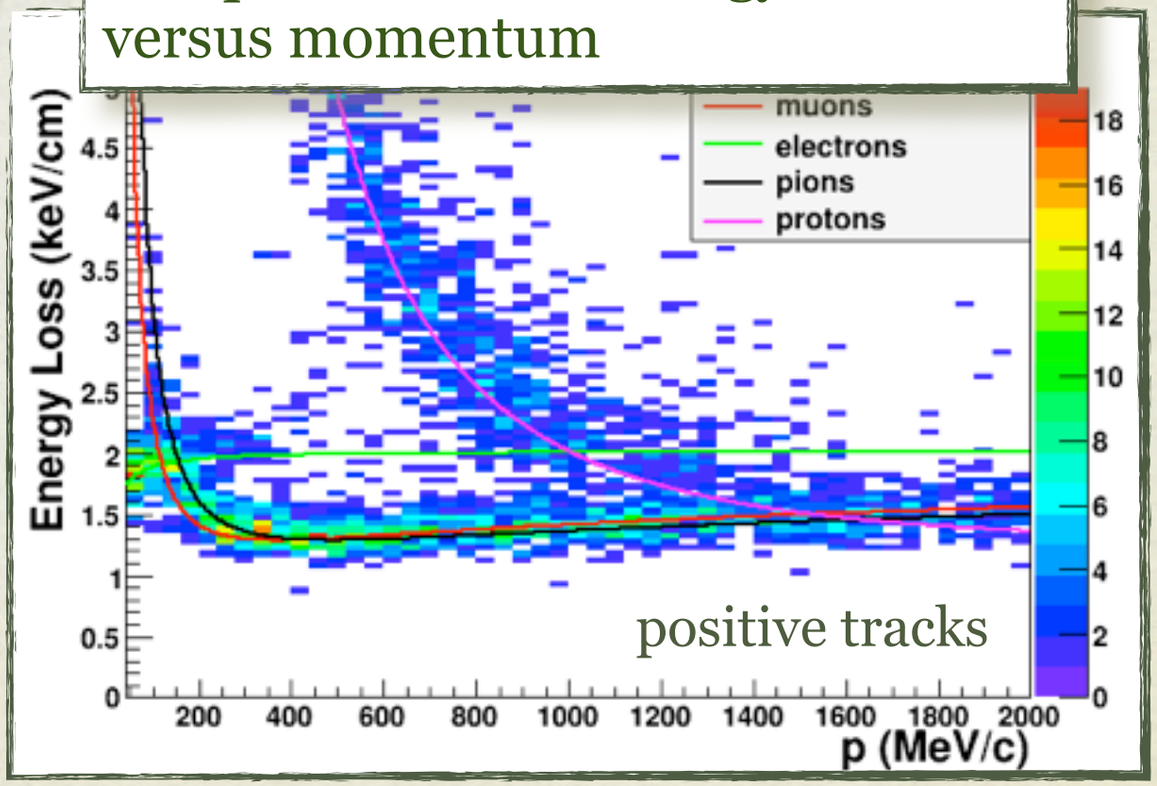
~ 9500 channels



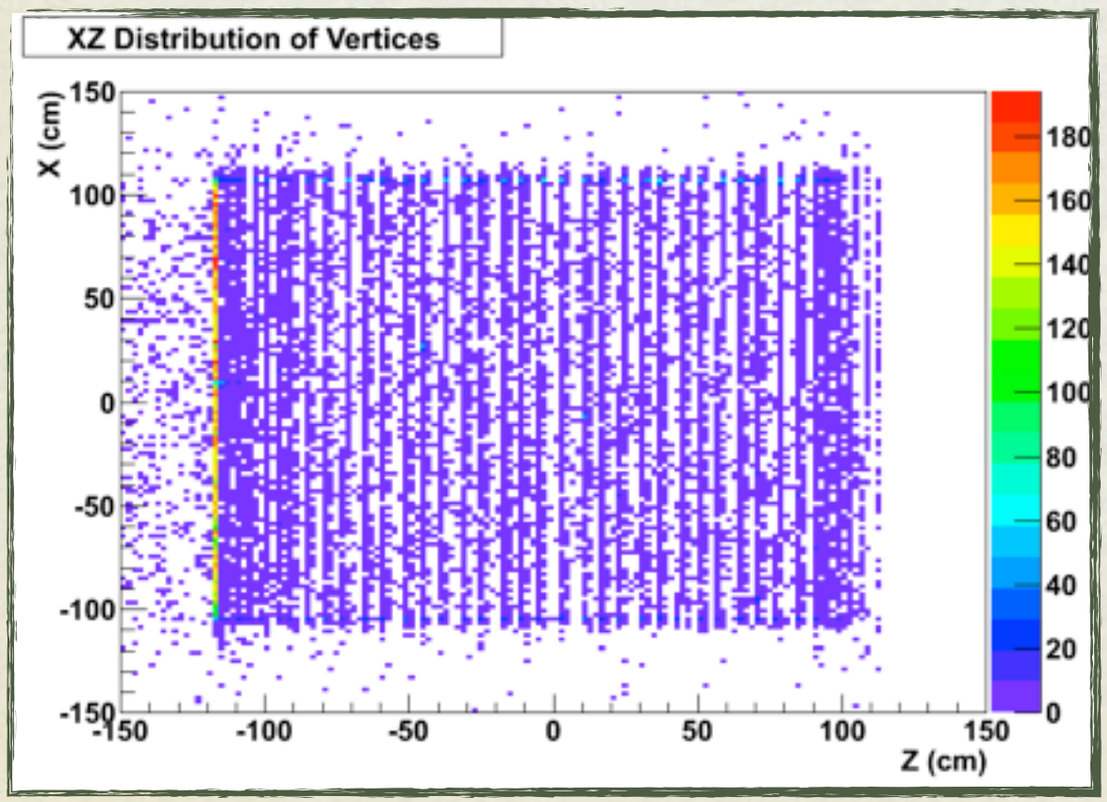
- Two detectors
  - 15 XY layers (192 bars)
  - 7 XY layers + 7 water panels



PID performance: Energy loss versus momentum

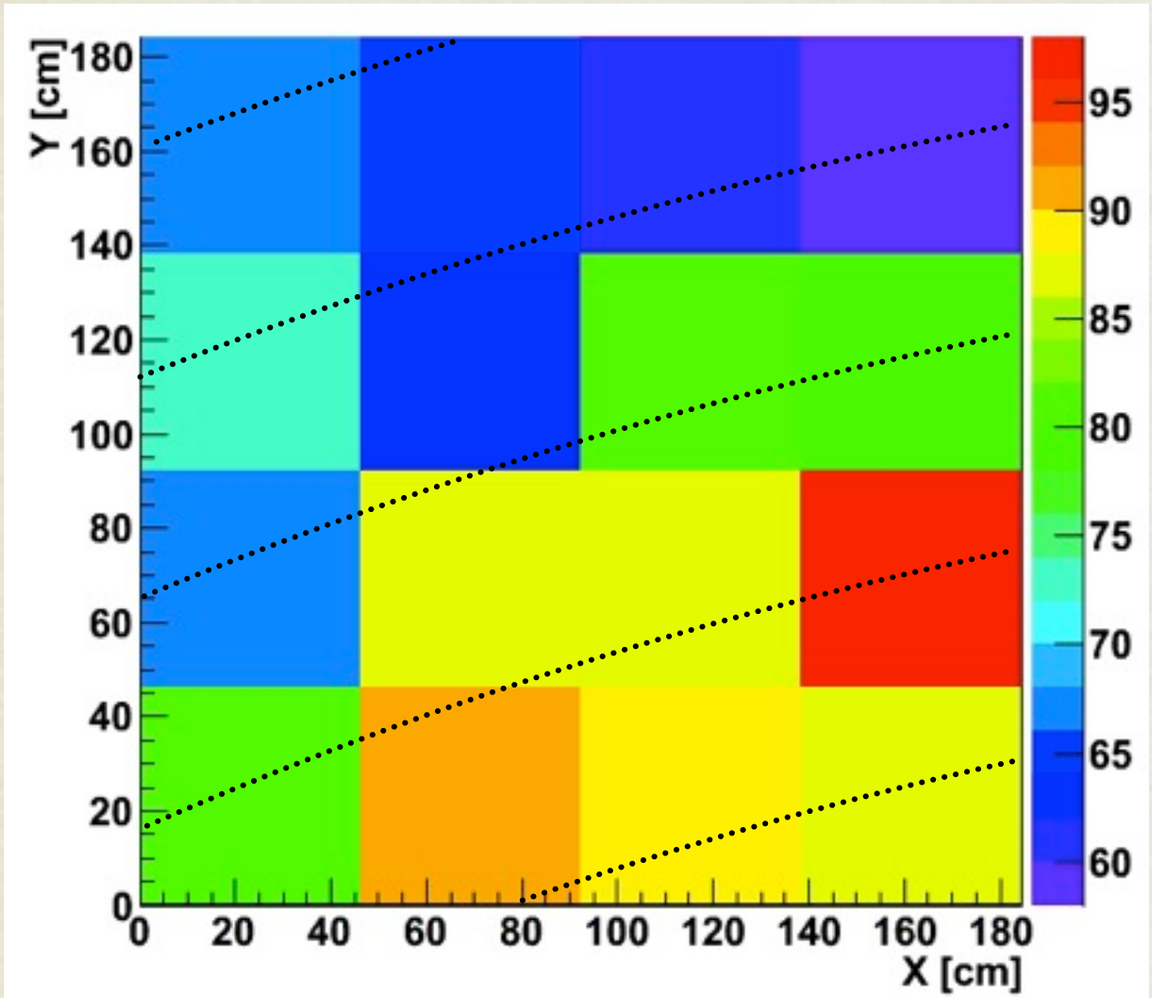


PoD: π^0 detector & DS ECAL



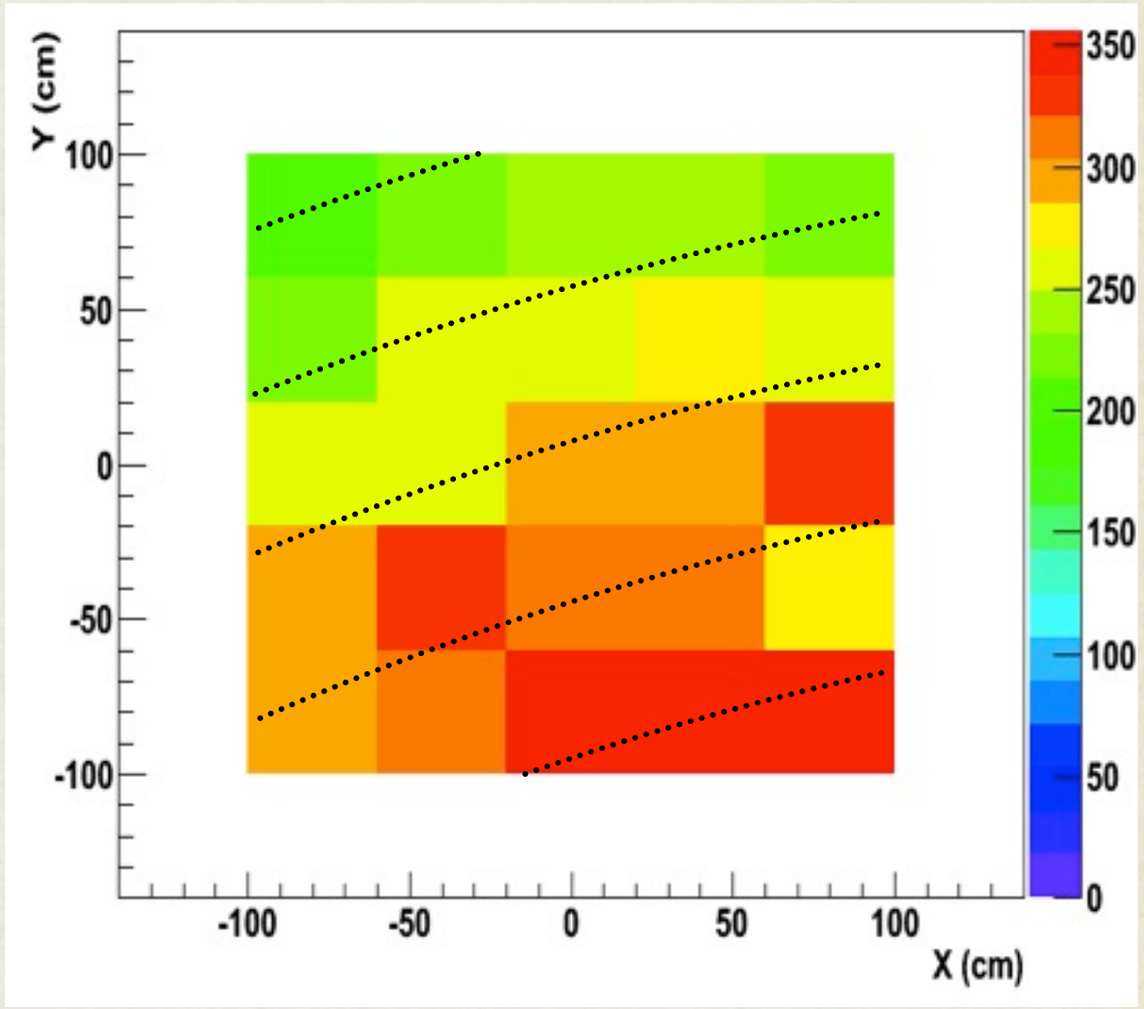
One of 4 supermodules of the P0D

The off-axis detector is really off-axis!



◀ FGD

POD ▶

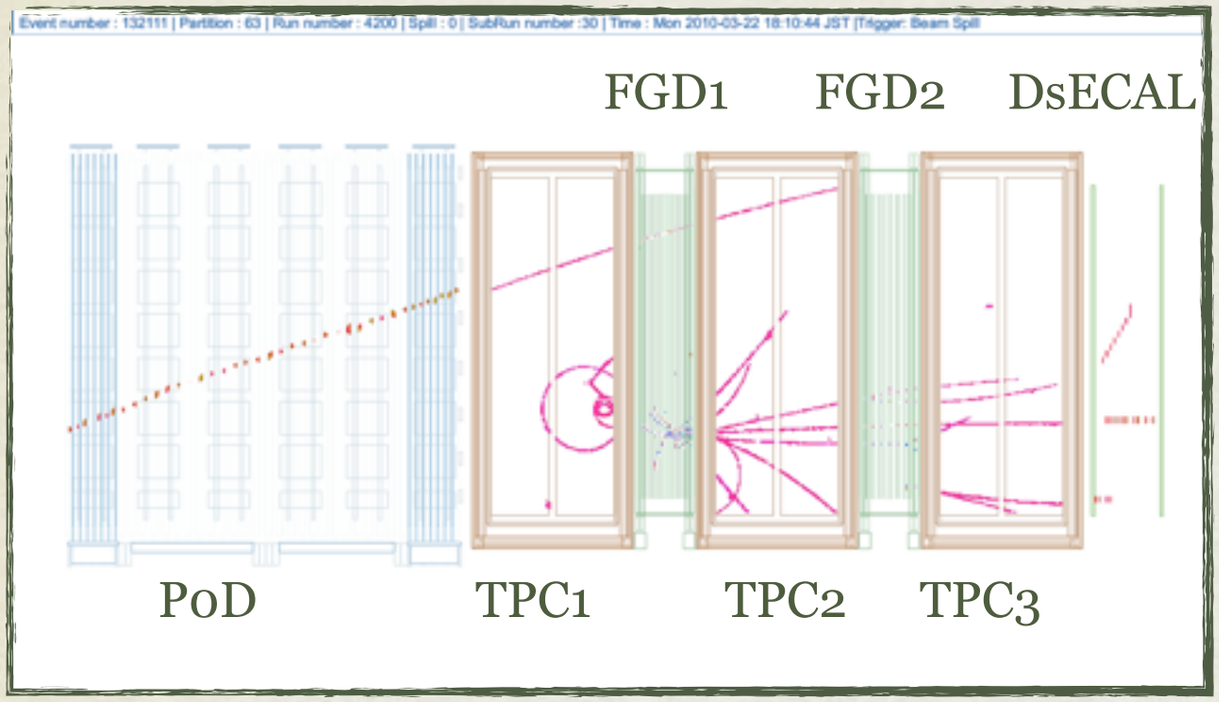


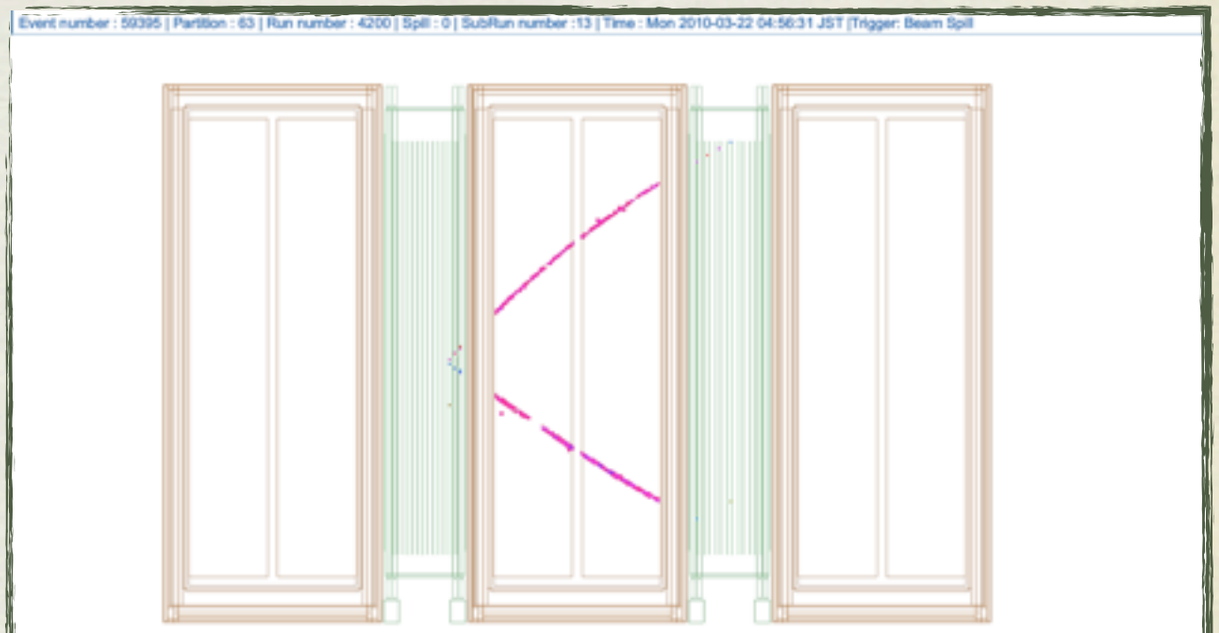
Contained vertices reconstructed in the 2 ‘Fiducial’ detectors.

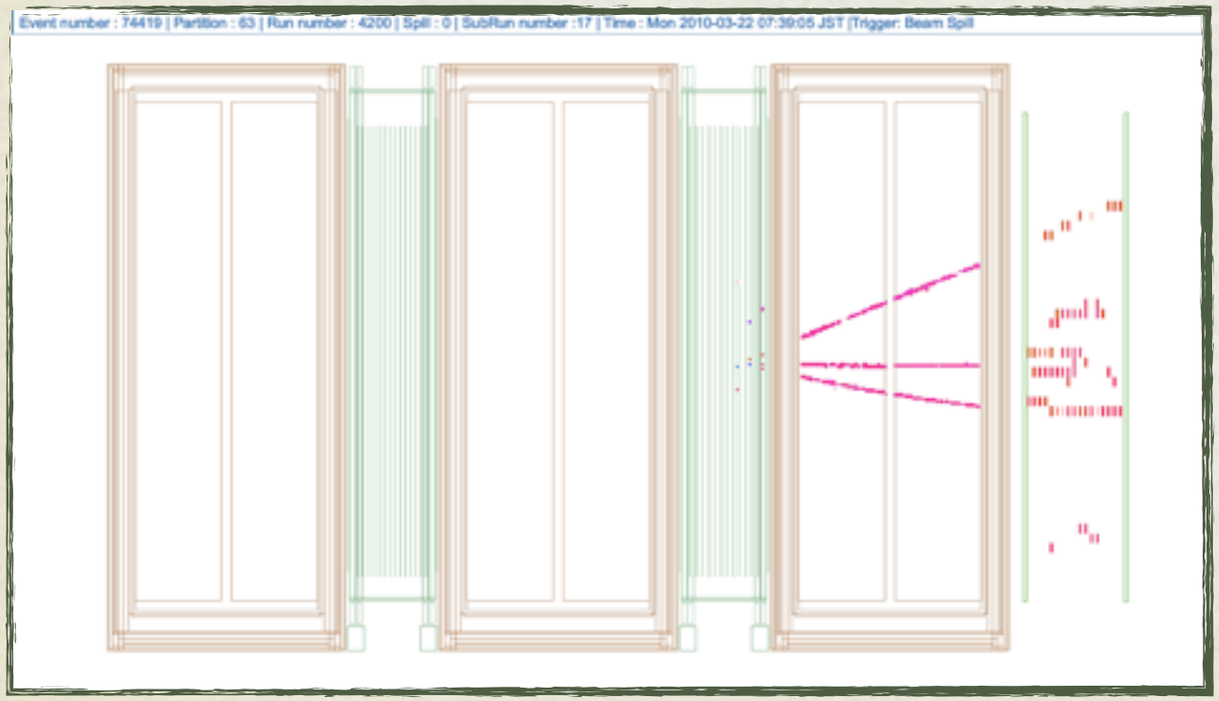
Lines show (approximate) iso-contours of off-axis angle.

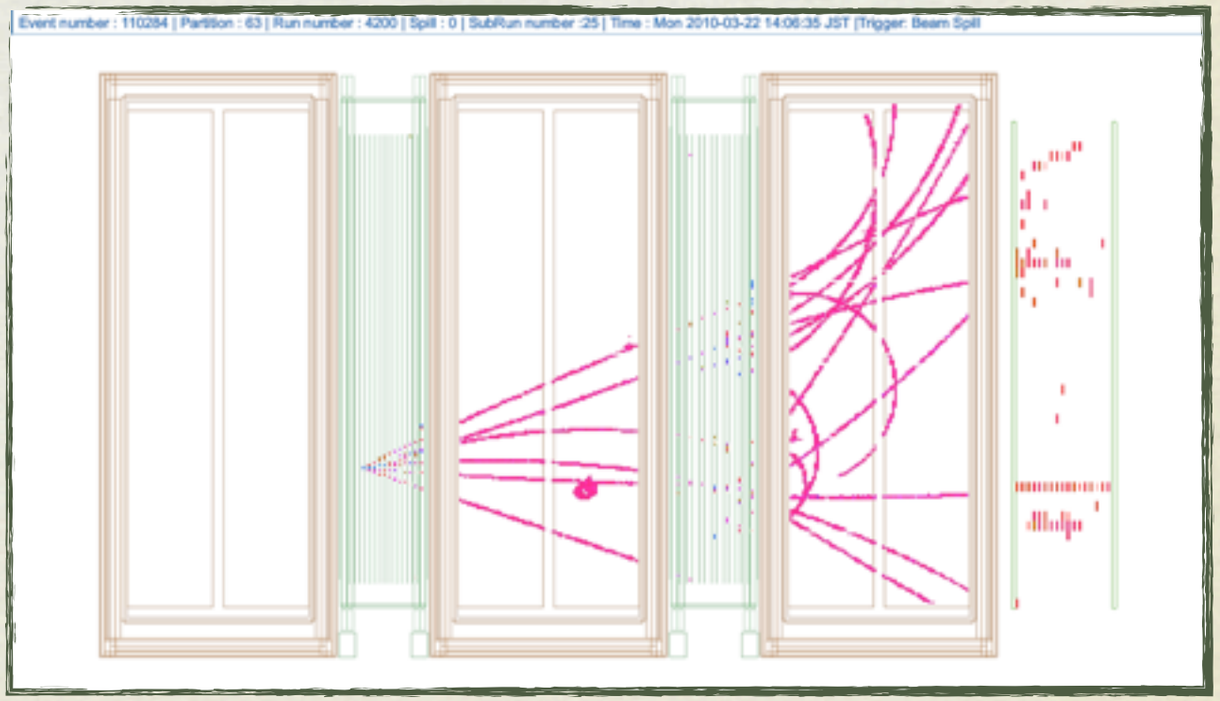
Outer corner is roughly 20% further off-axis than inner corner.

Overview of events in the off-axis ND280







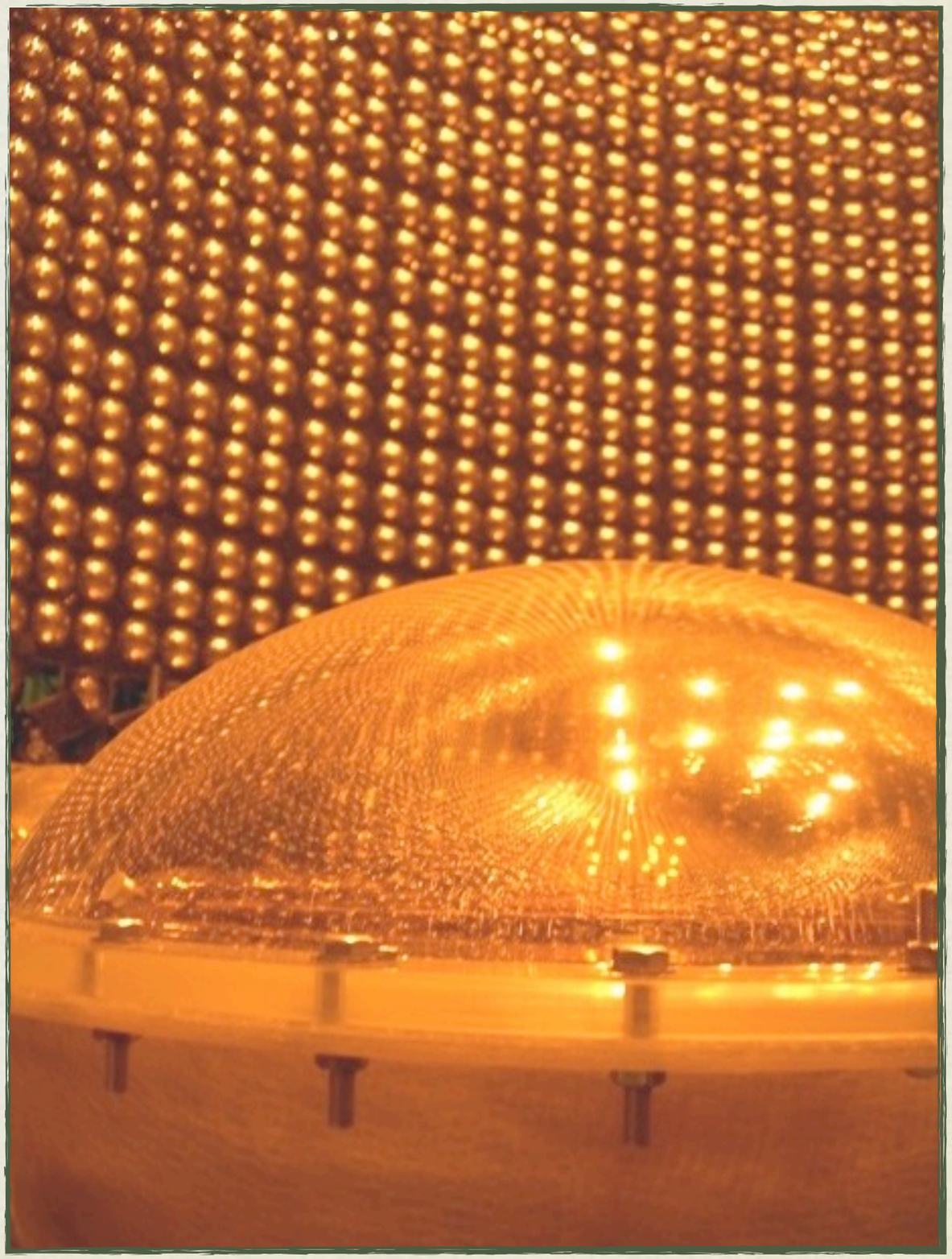


Super-Kamiokande overview

Event rate

Vertex distributions

Event displays

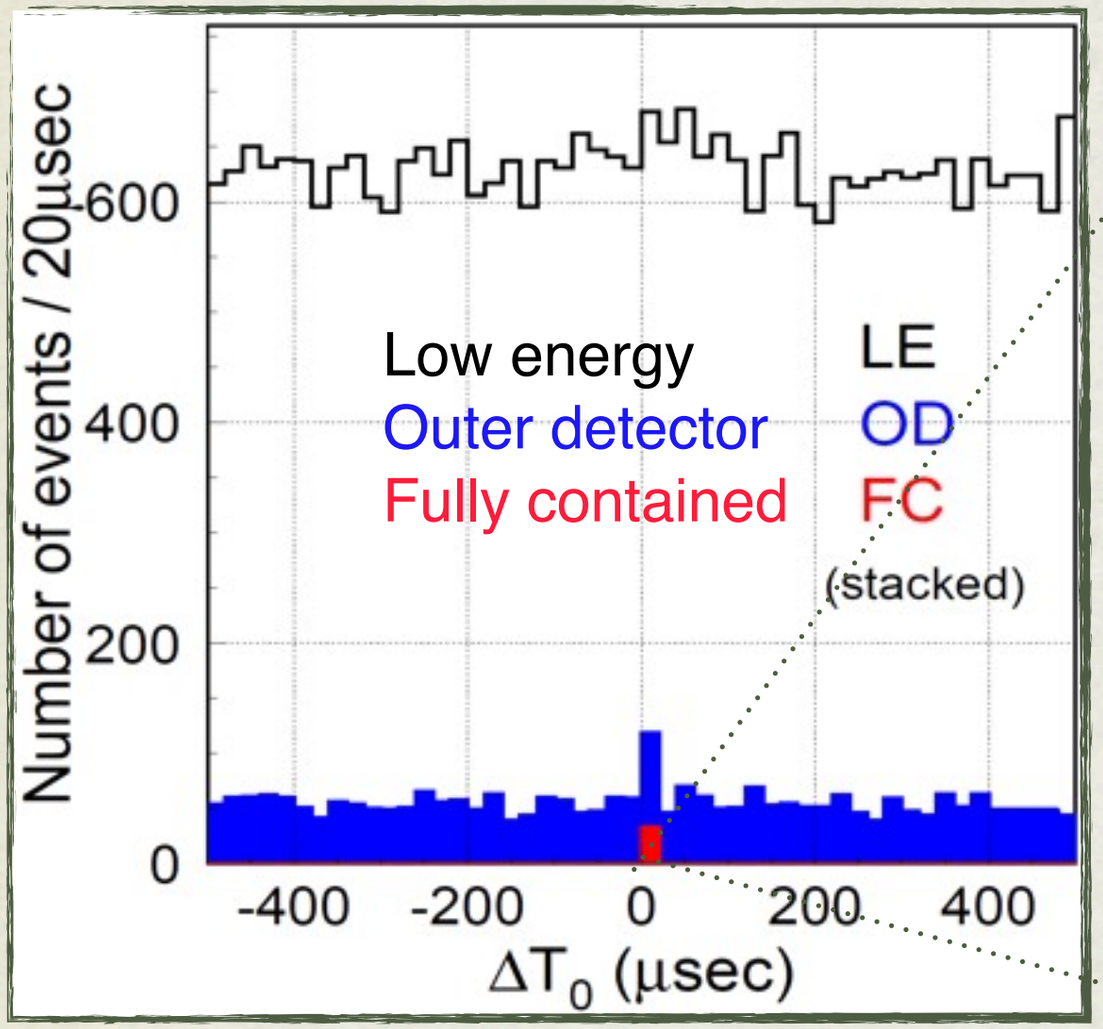


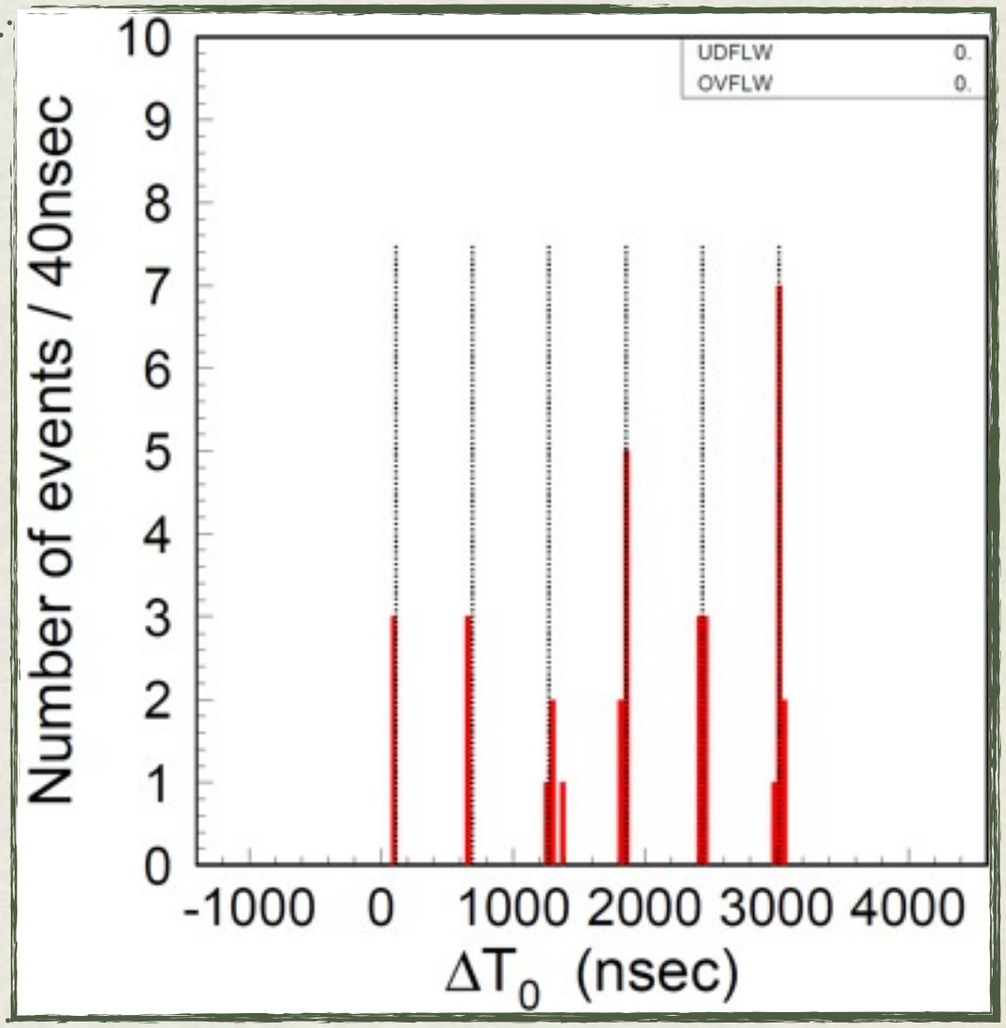
Event rates and timing

ΔT_0 : relative event time to the spill time

ΔT_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

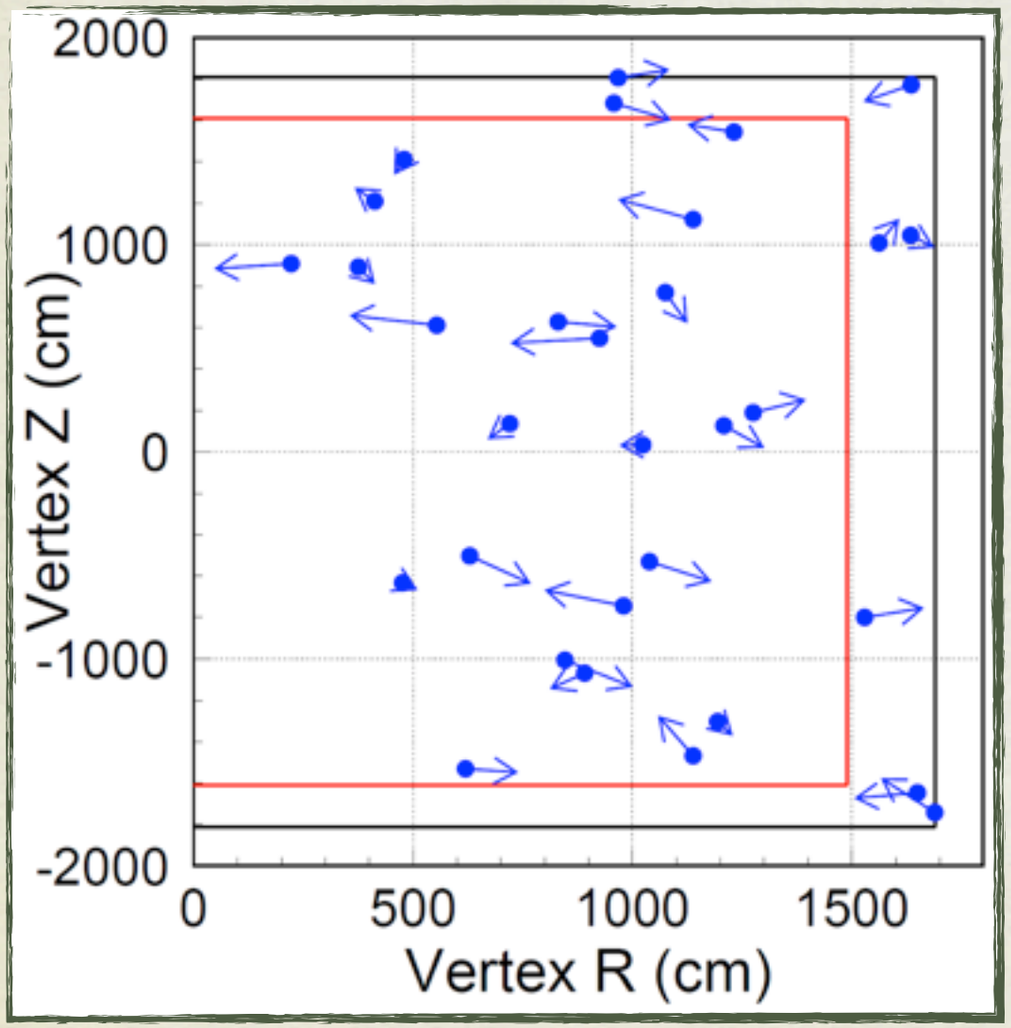
Super-Kamiokande status - Selection cuts

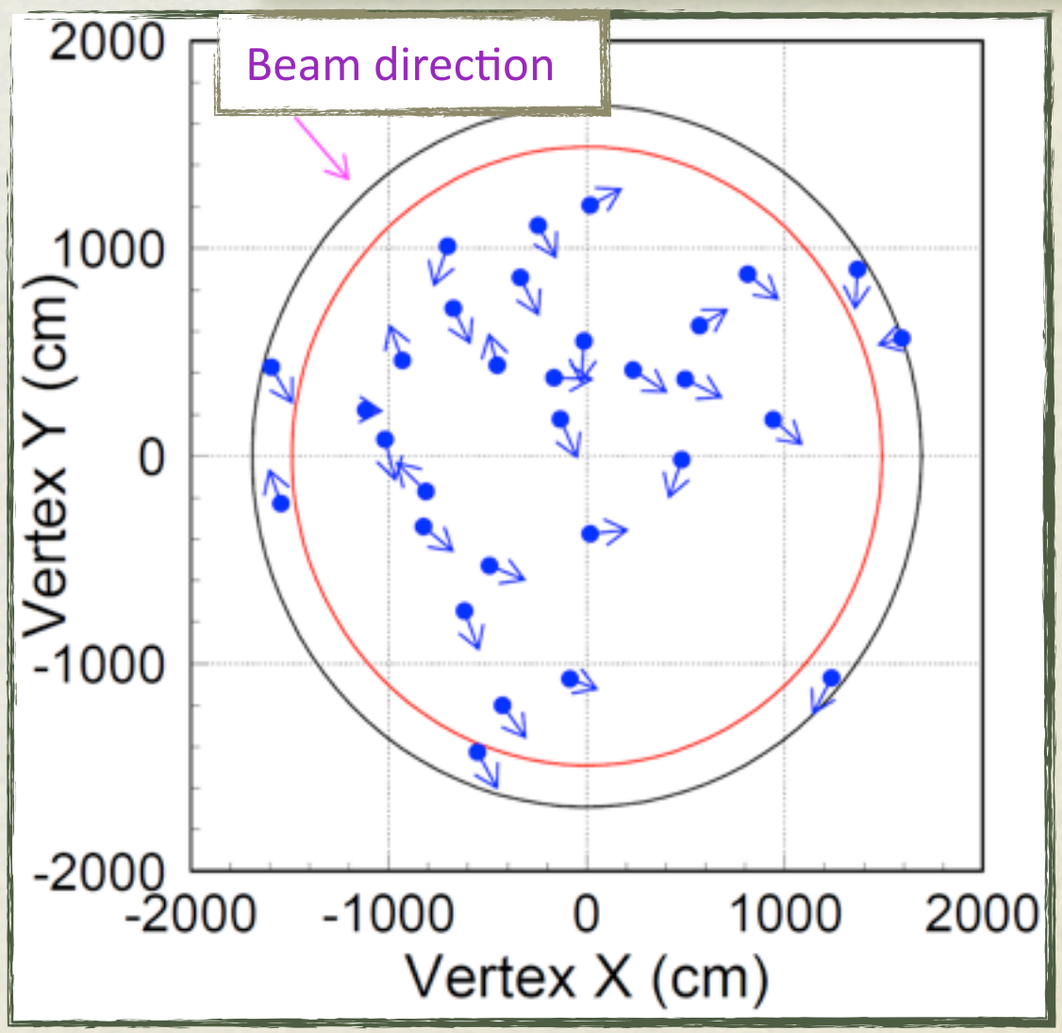
For ν_μ disappearance analysis	For ν_e appearance search
Timing coincident w/ beam time (+TOF)	
Fully contained (No OD activity)	
Vertex in fiducial volume (Vertex >2m from wall)	
E_{vis} > 30MeV	E_{vis} > 100MeV
nº of rings =1	
μ-like ring	**e-like ring**
	No decay electron
	Inv. mass w/ forced-found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

Event rates and vertex distributions

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

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

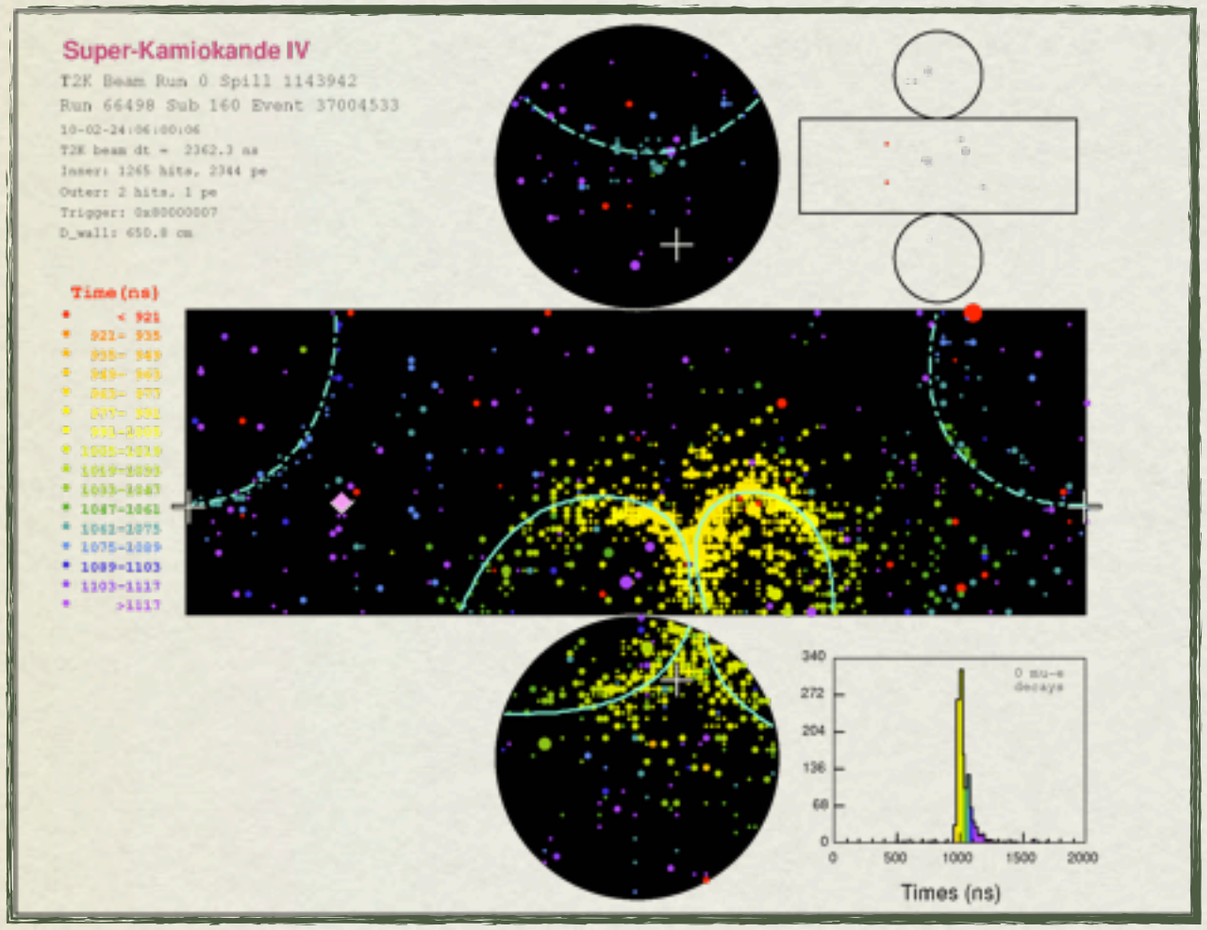


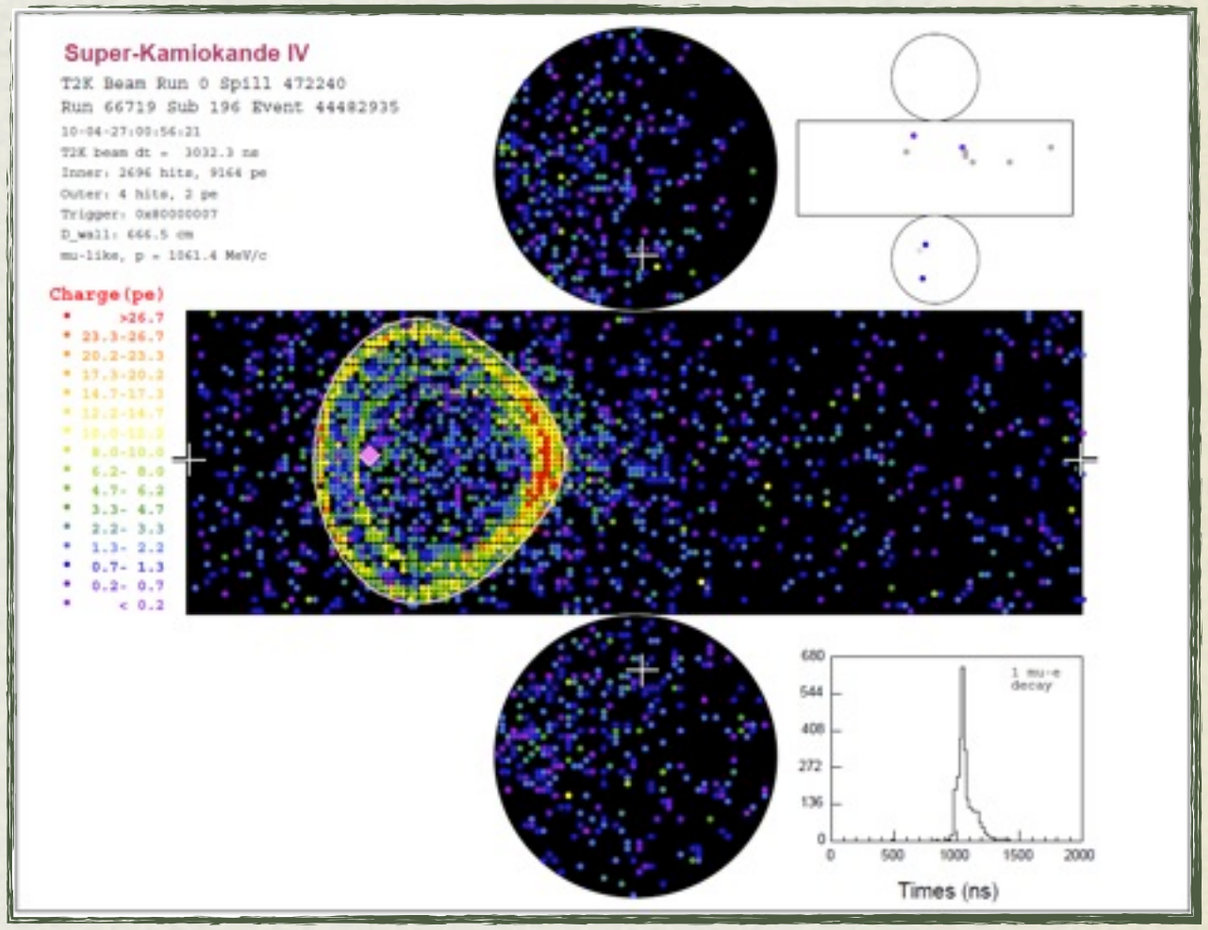


Vertices are evenly distributed throughout the detector

Events in Super-Kamiokande

February 24th 2010! First event!





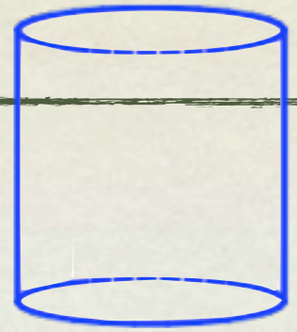
[1st ring + 2nd ring]
Invariant mass: 133.8 MeV/c²
(close to π^0 mass)
Momentum: 148.3 MeV/c

<u>Single ring mu-like</u>

P_μ= 1061 MeV/c -- 1 decay electron

April 27th, 2010

Events in Super-Kamiokande



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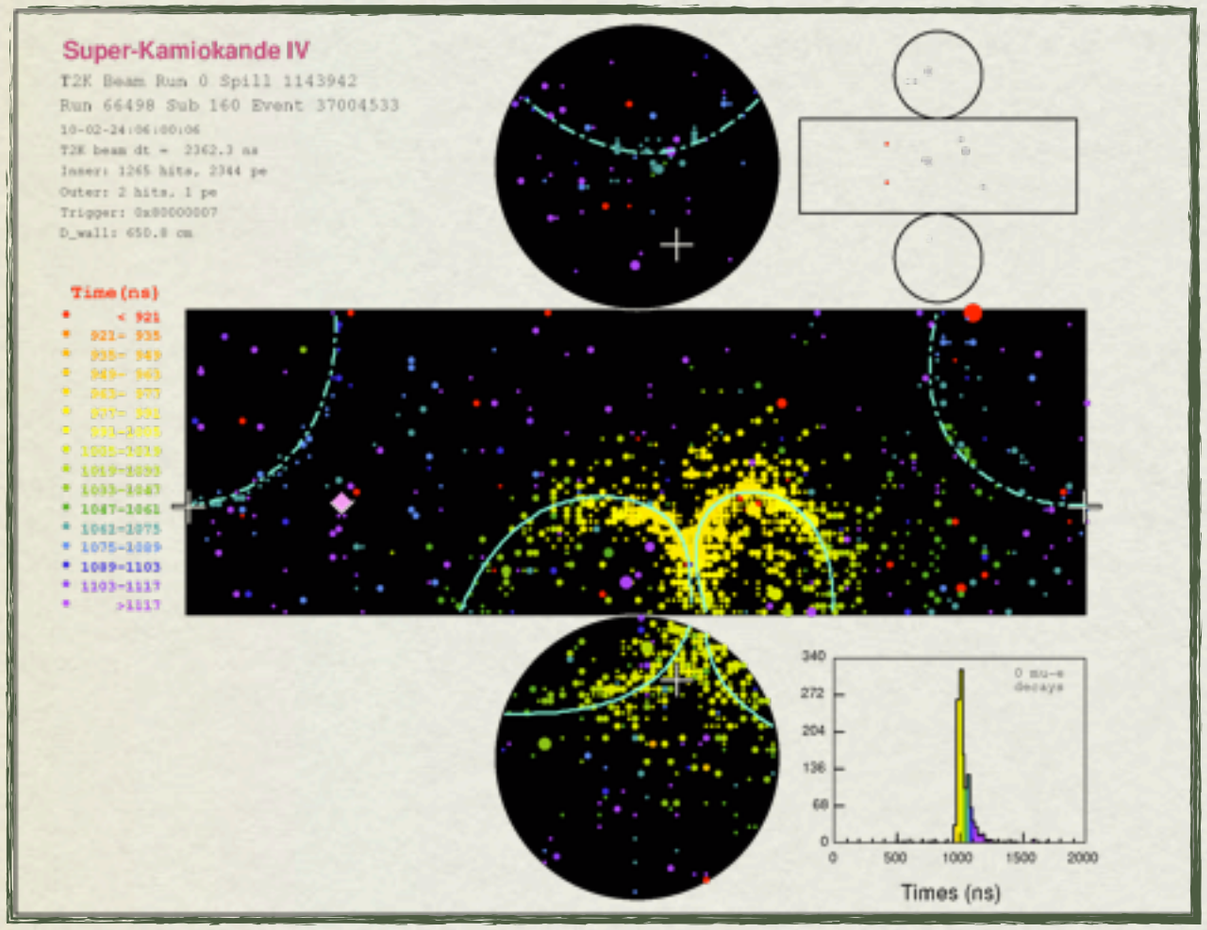

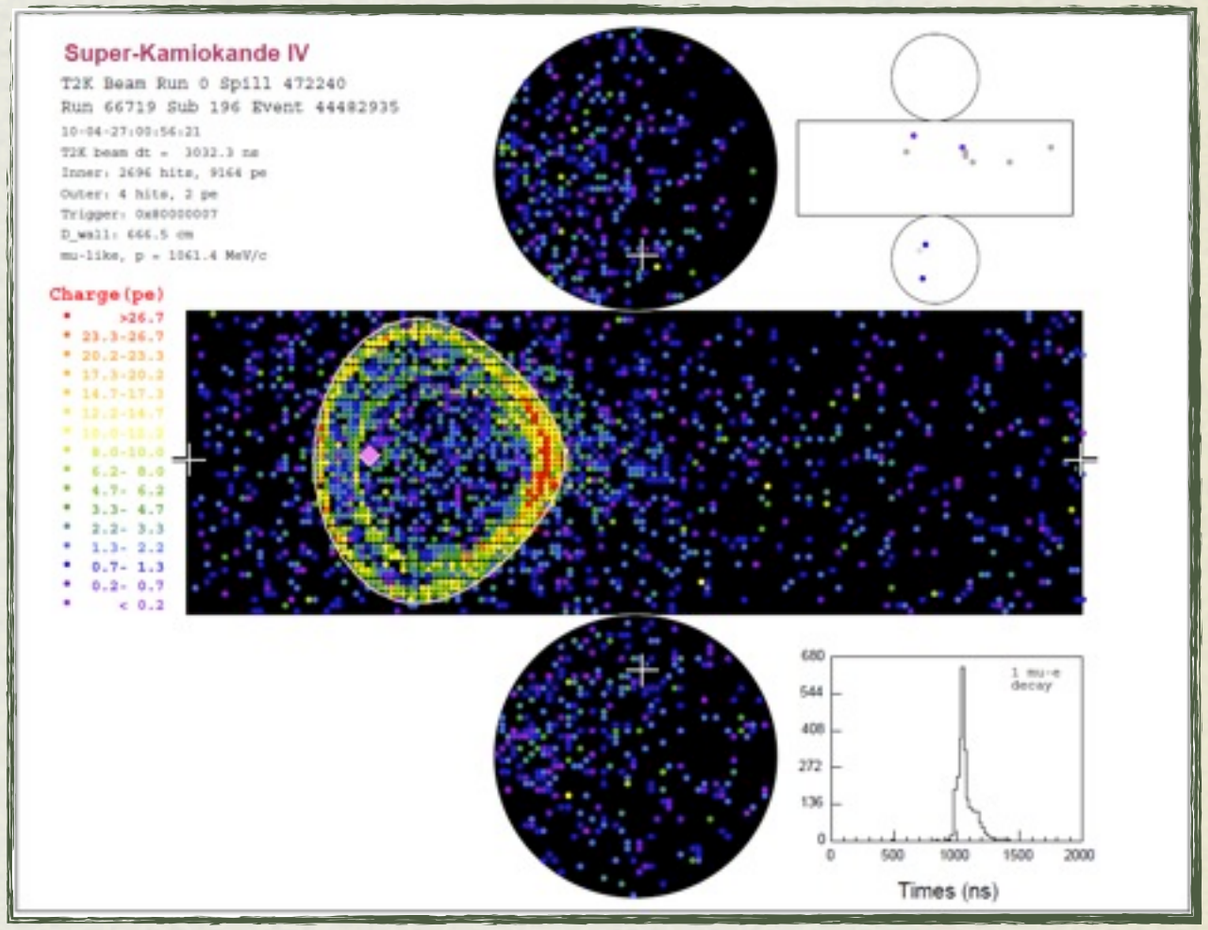

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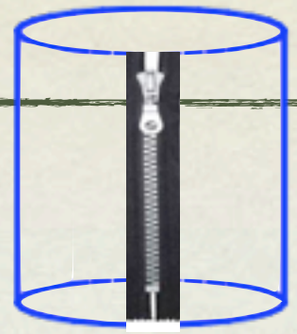
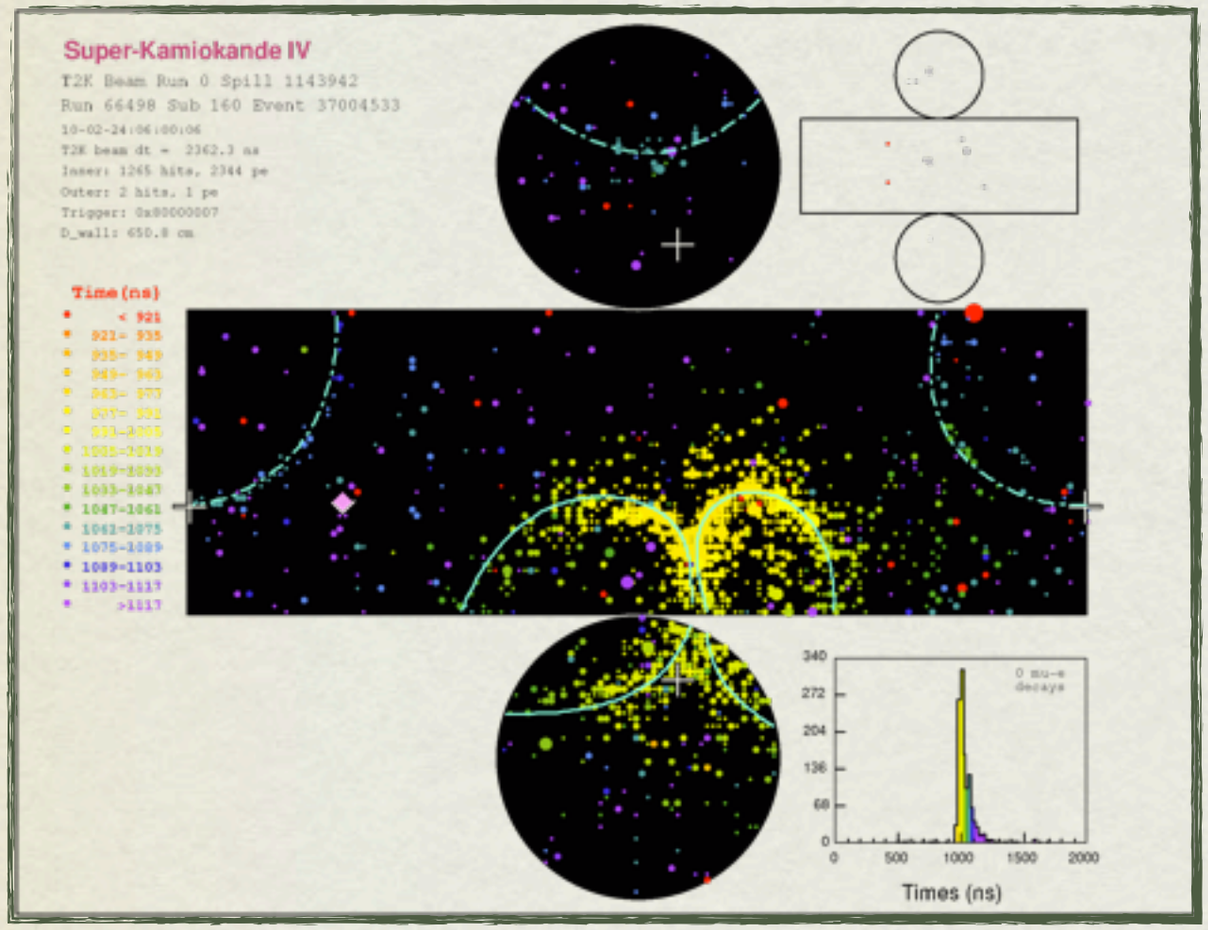


February 24th 2010! First event!



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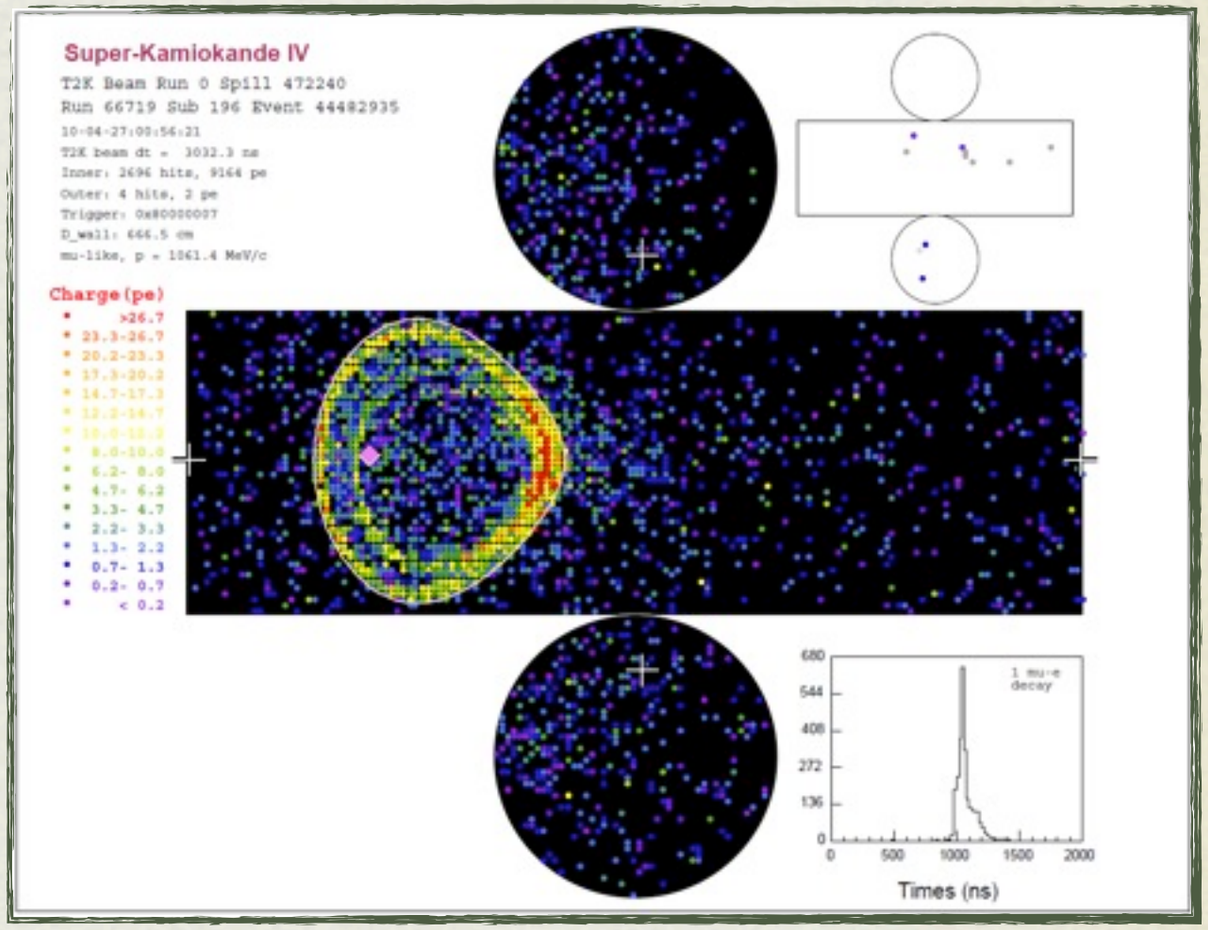
Momentum: 148.3 MeV/c



Single ring mu-like

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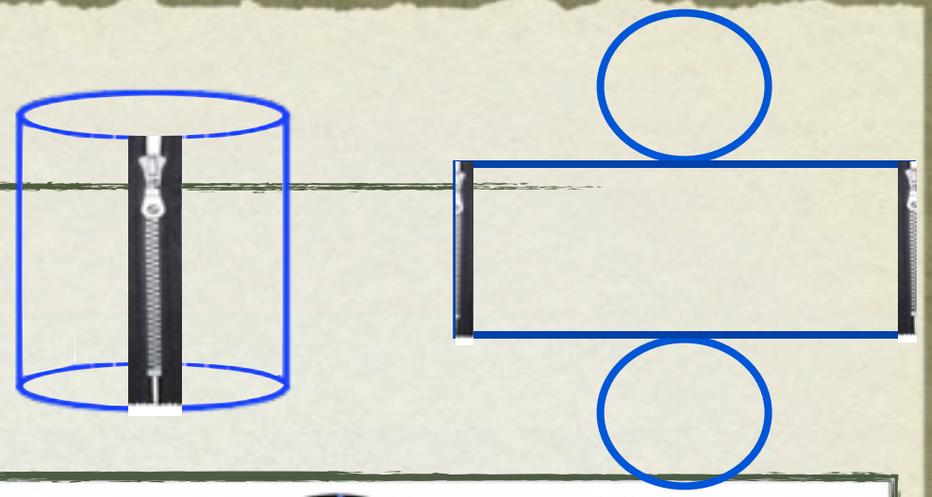
April 27th, 2010

Events in Super-Kamiokande



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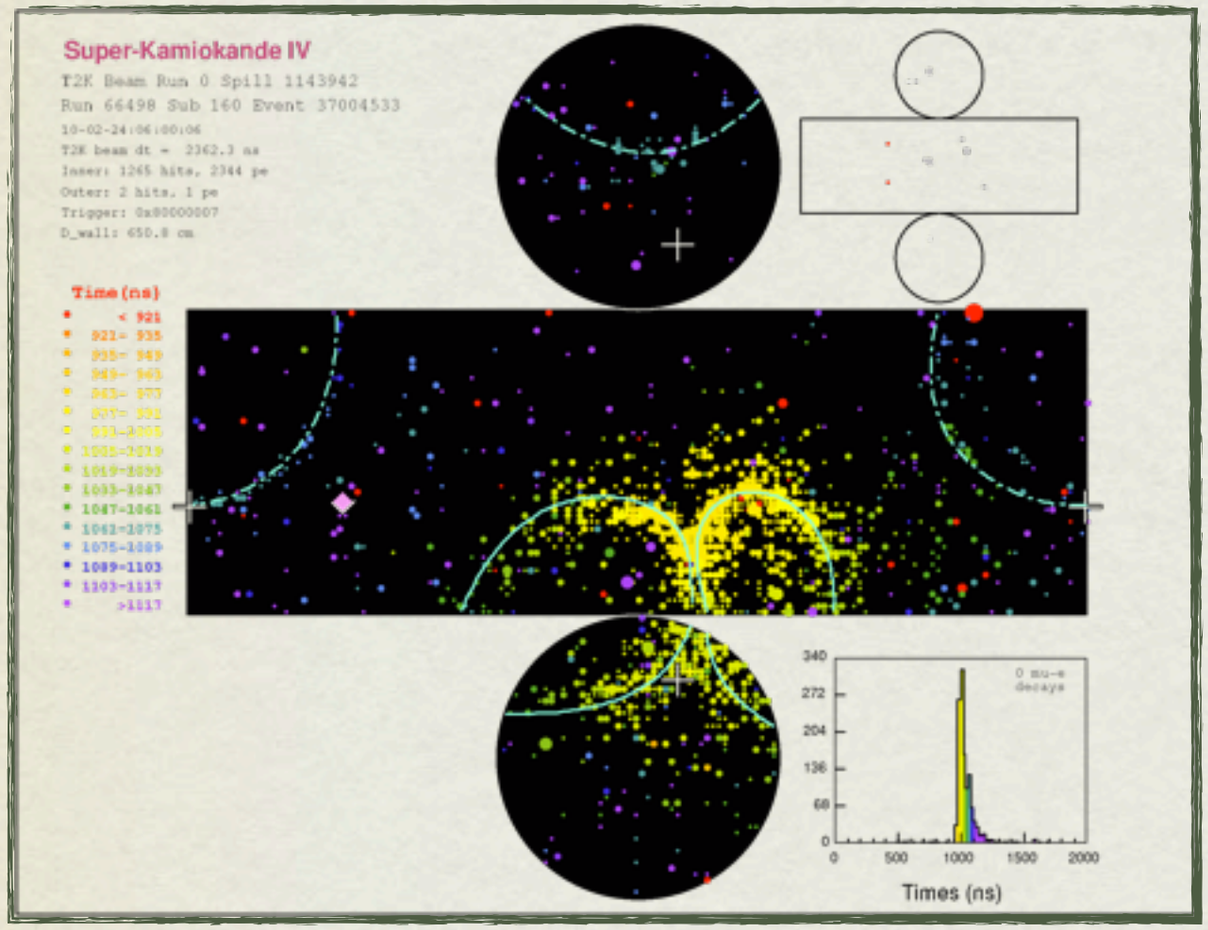

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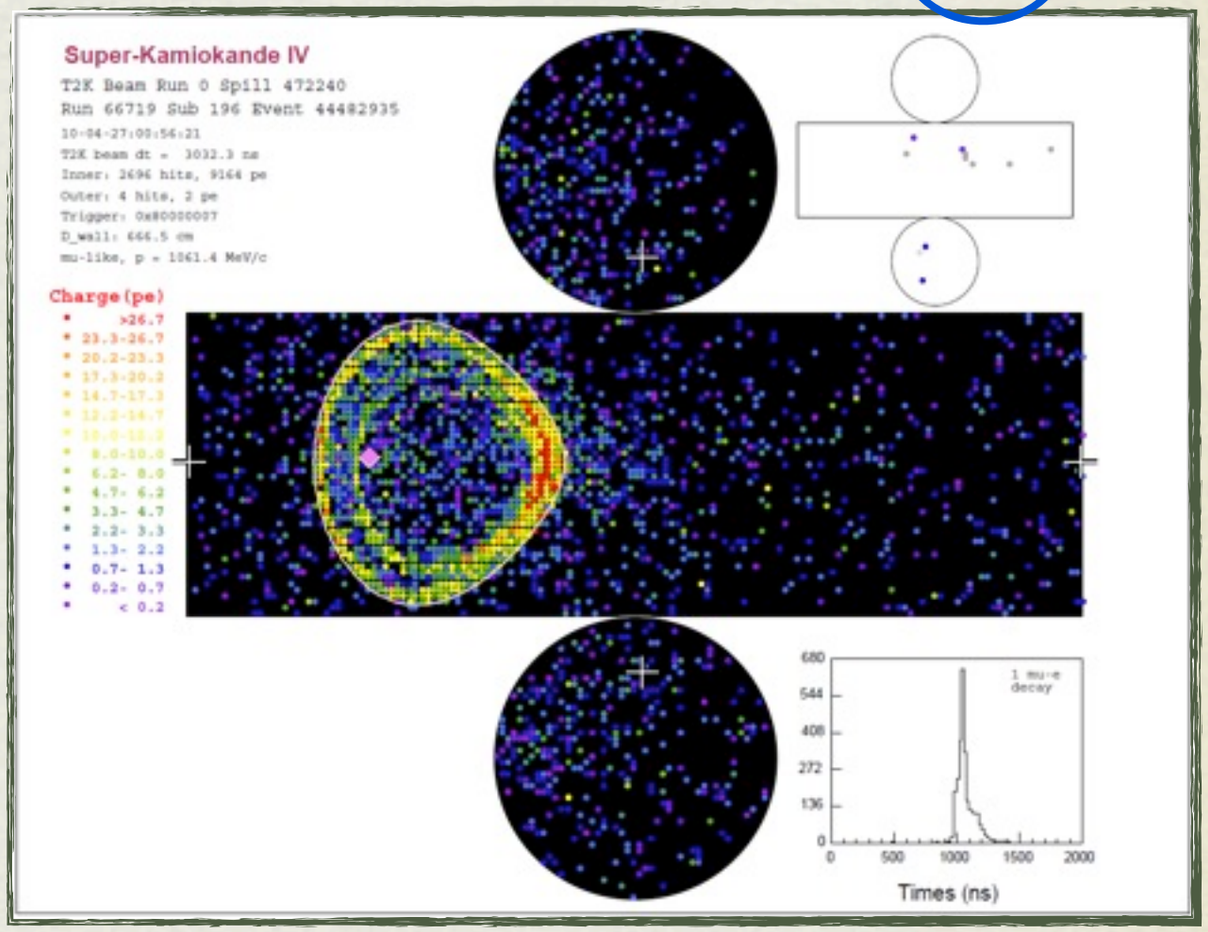


Single ring mu-like

P_μ= 1061 MeV/c -- 1 decay electron

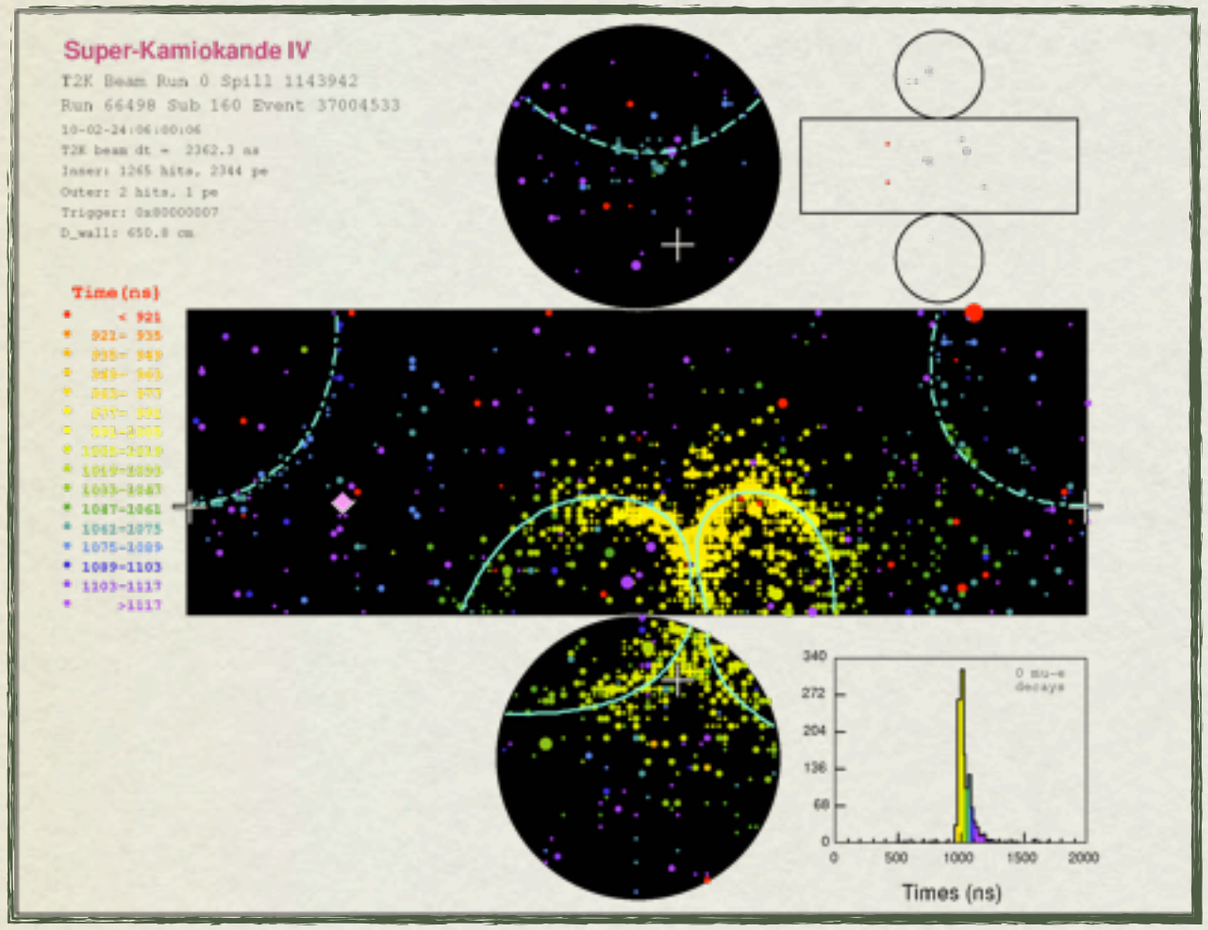
April 27th, 2010

Events in Super-Kamiokande

Super-K is a water Cherenkov detector:

- Electrons create electro-magnetic showers → fuzzy ring
- Muons do not make shower → clear ring

February 24th 2010! First event!



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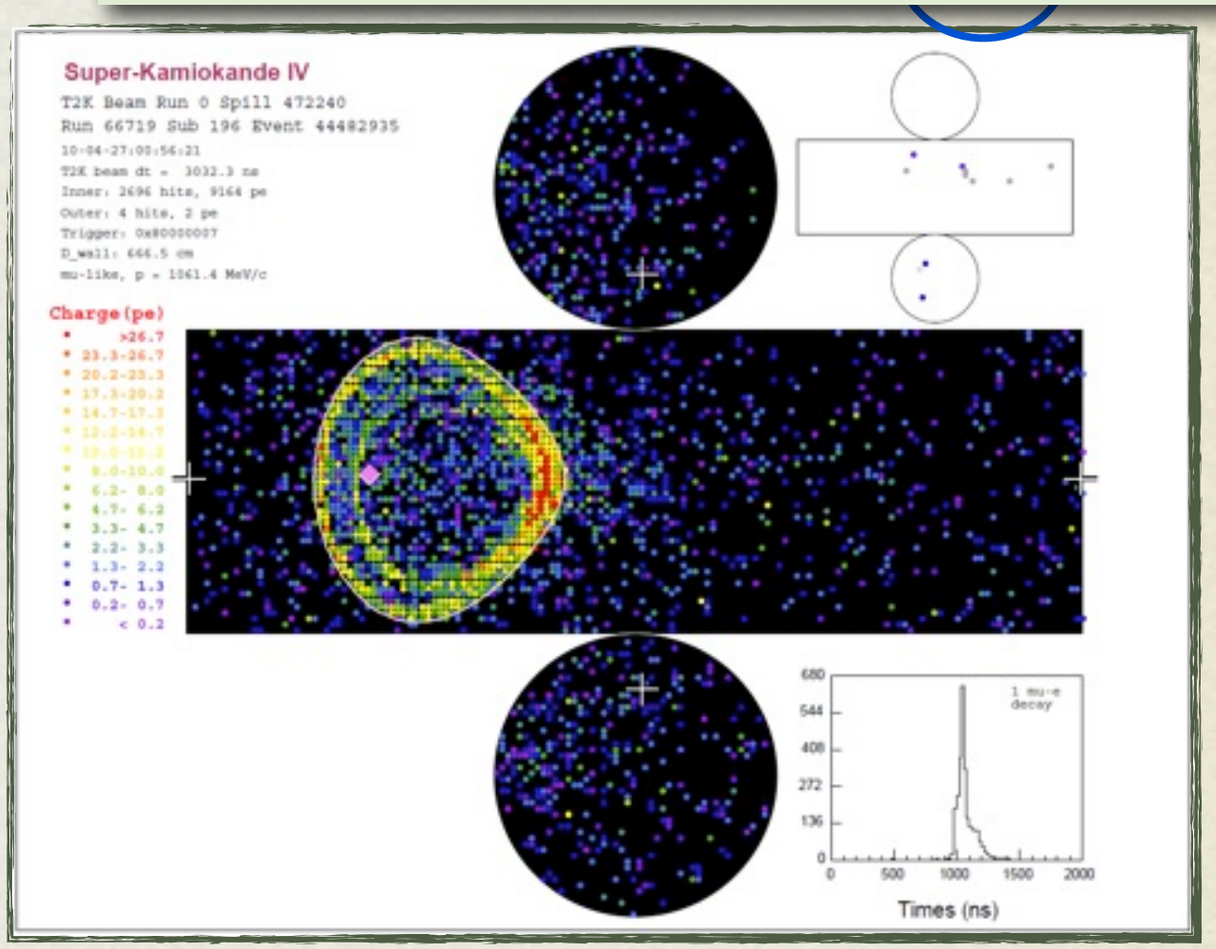


<u>Single ring mu-like</u>

P_μ= 1061 MeV/c -- 1 decay electron

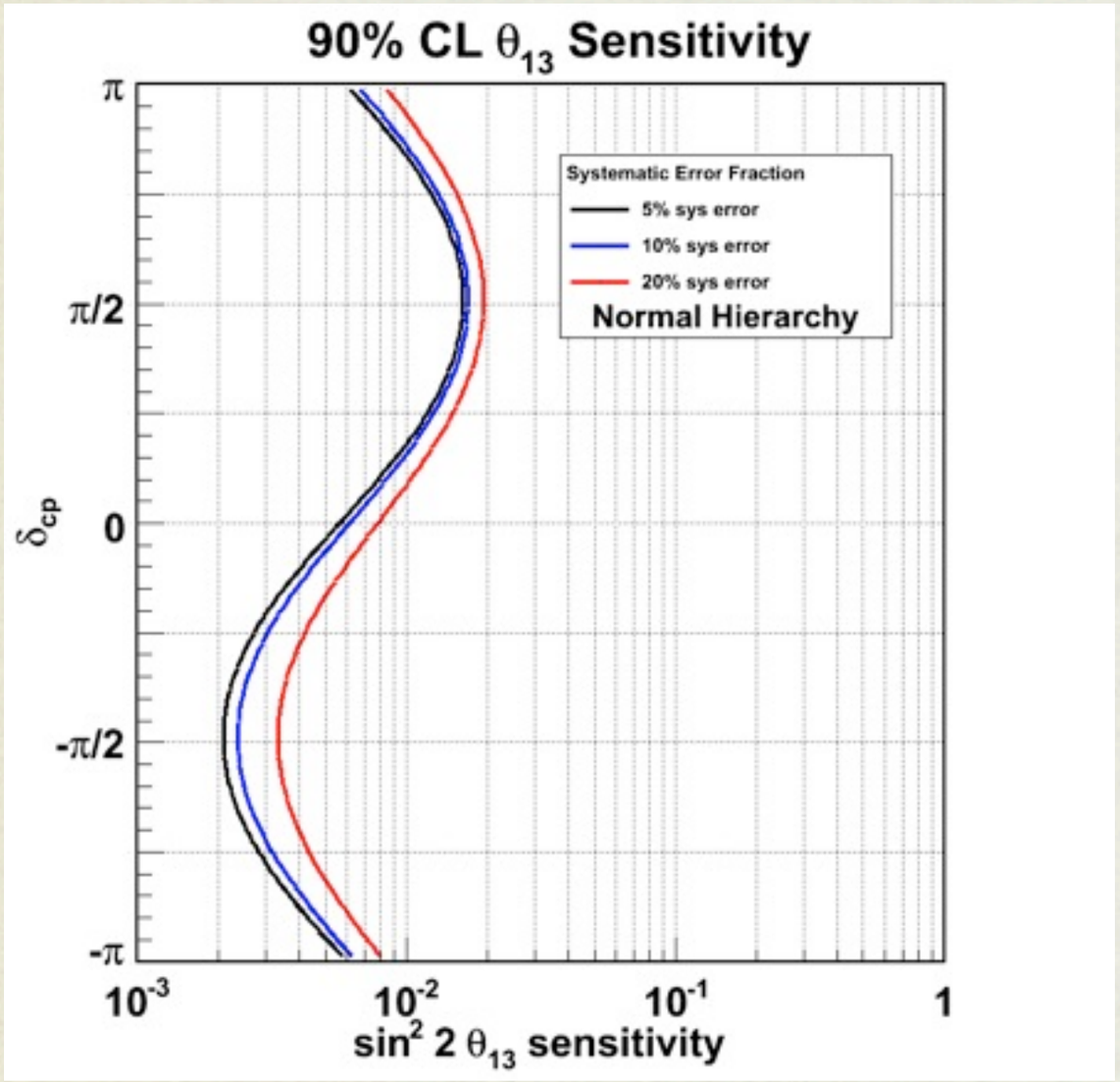
April 27th, 2010

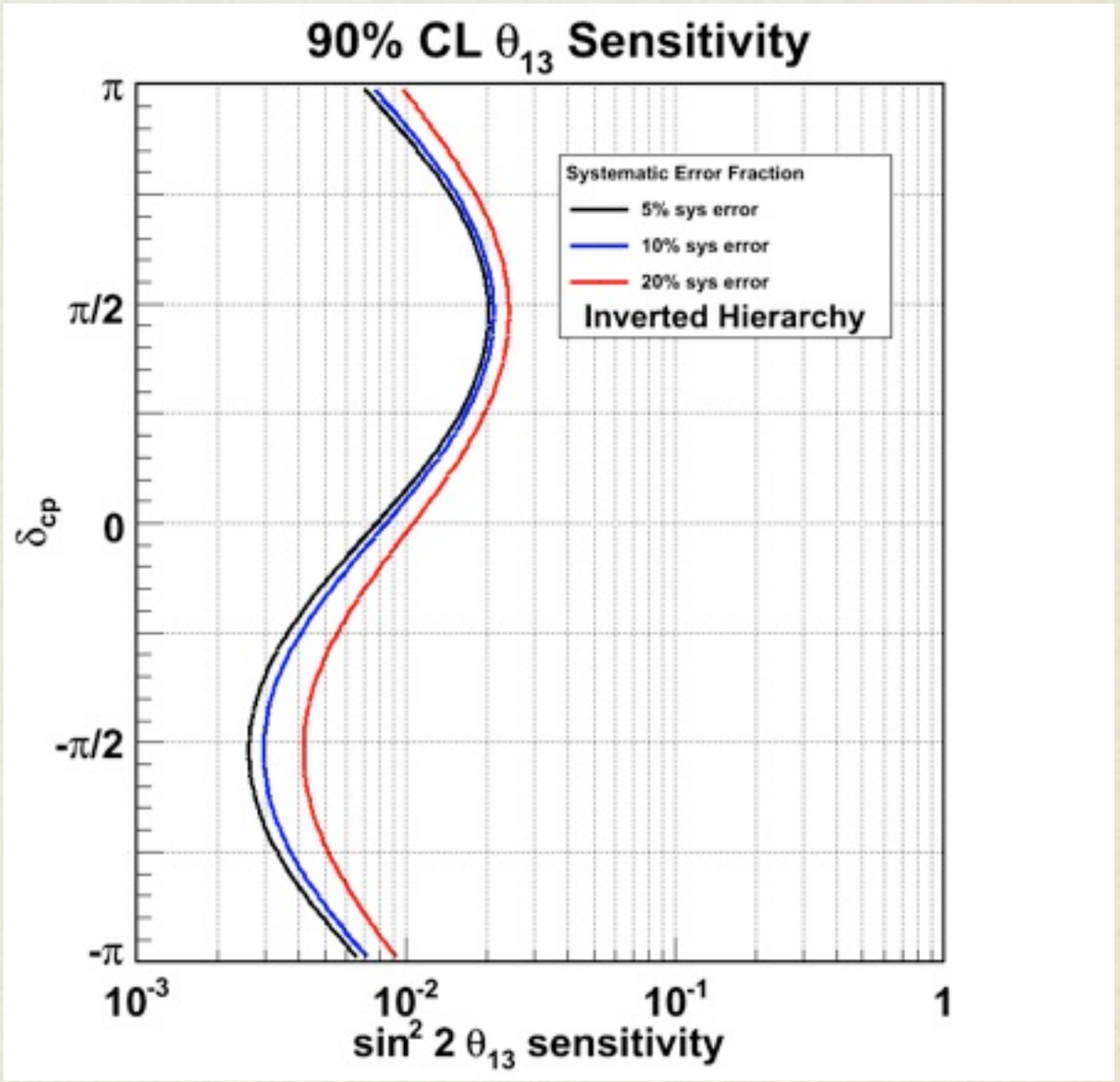
Conclusions

- T2K experiment is now fully operational and taking data
- First data taking period in 2010 accumulated 3.23 10^{19} @ 30 GeV p.o.t. and proton intensity increasing steadily
- Very hard work has been done on the beamline: everything is going great.
- Superb detector performance both at ND280 and SK
  - ECAL installation is now completed and we restarted taking data @ 100 kW
- Preparing first physics result from 1st physics run.

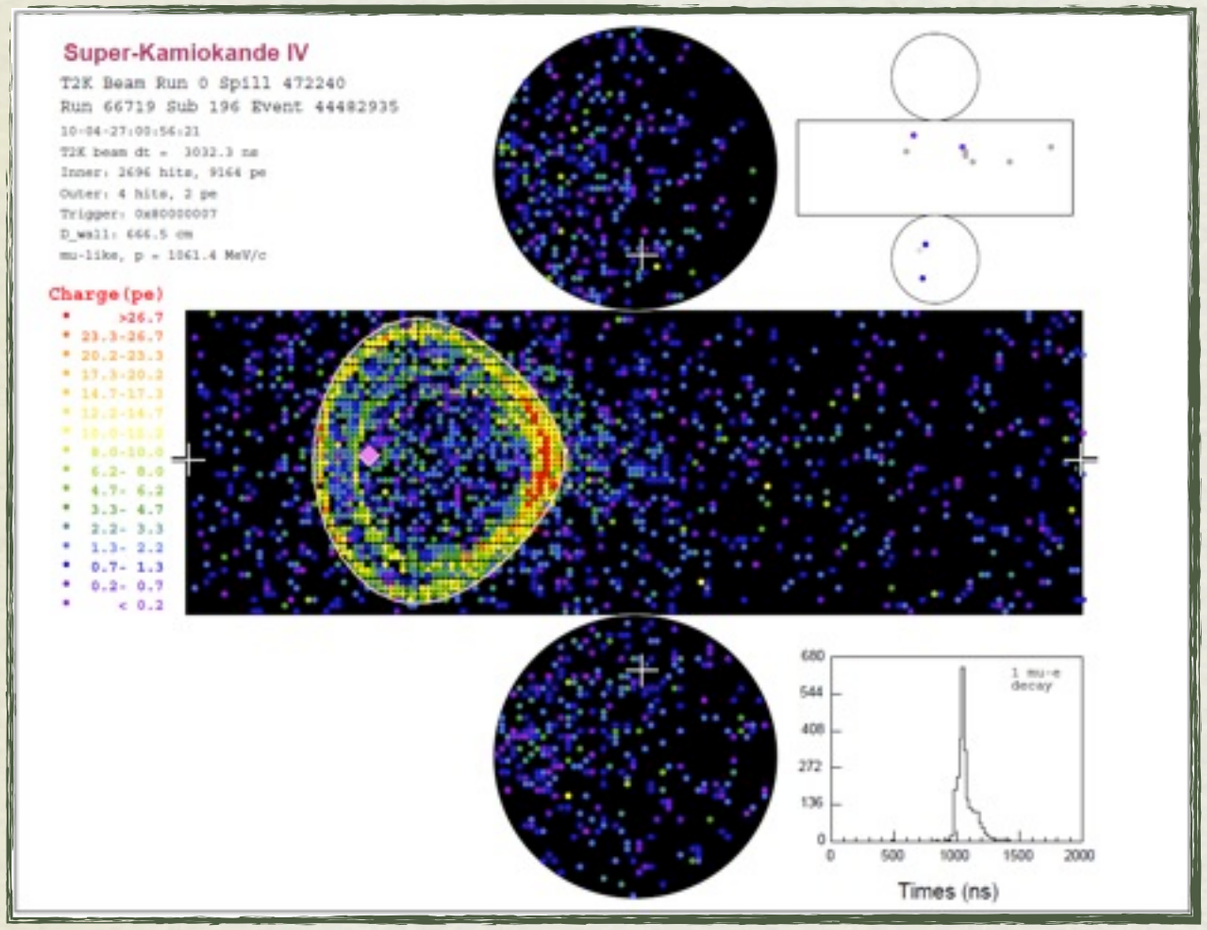
Backups

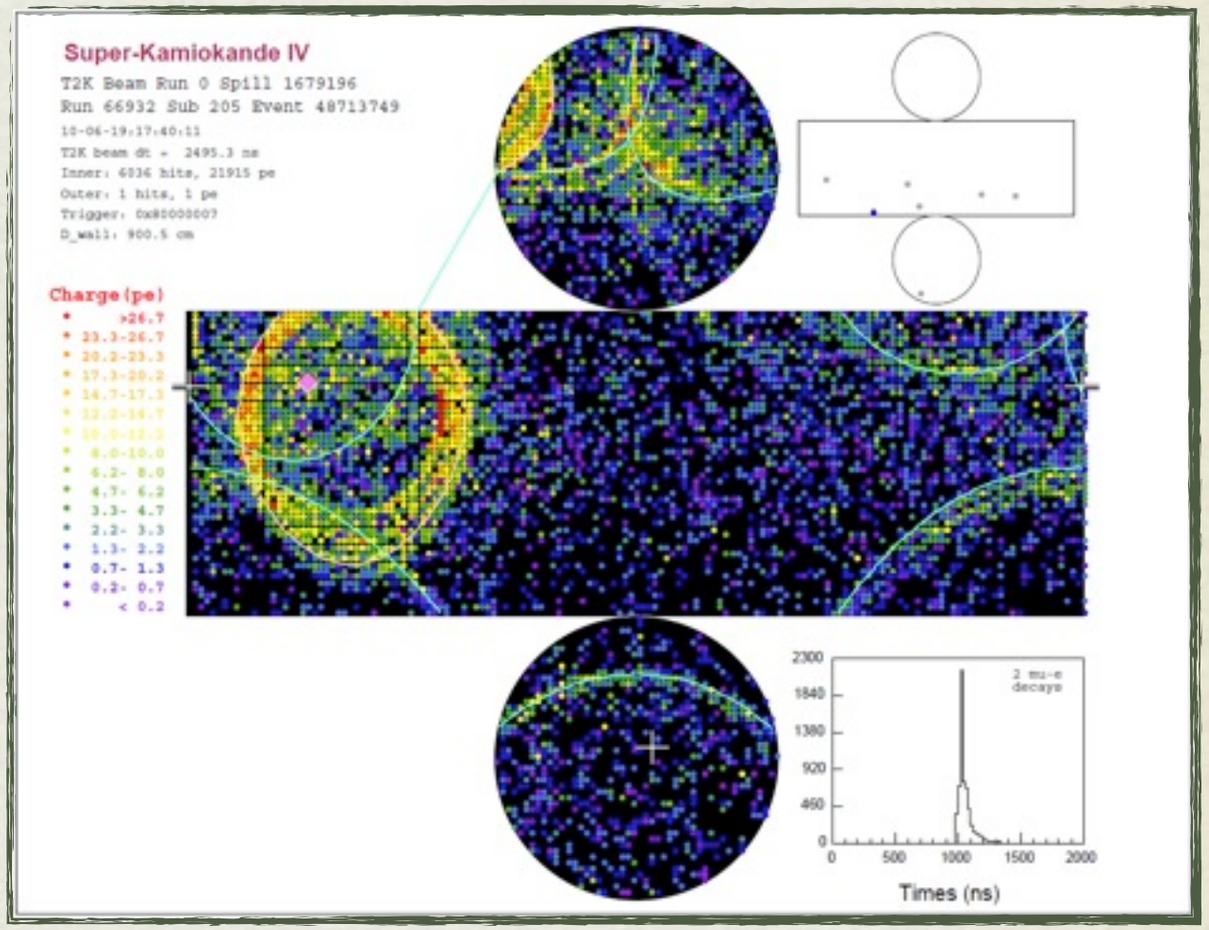
Sensitivity as a function of CP violation phase





Two more mu-like events





Single ring mu-like

P_μ= 1061 MeV/c -- 1 decay electron

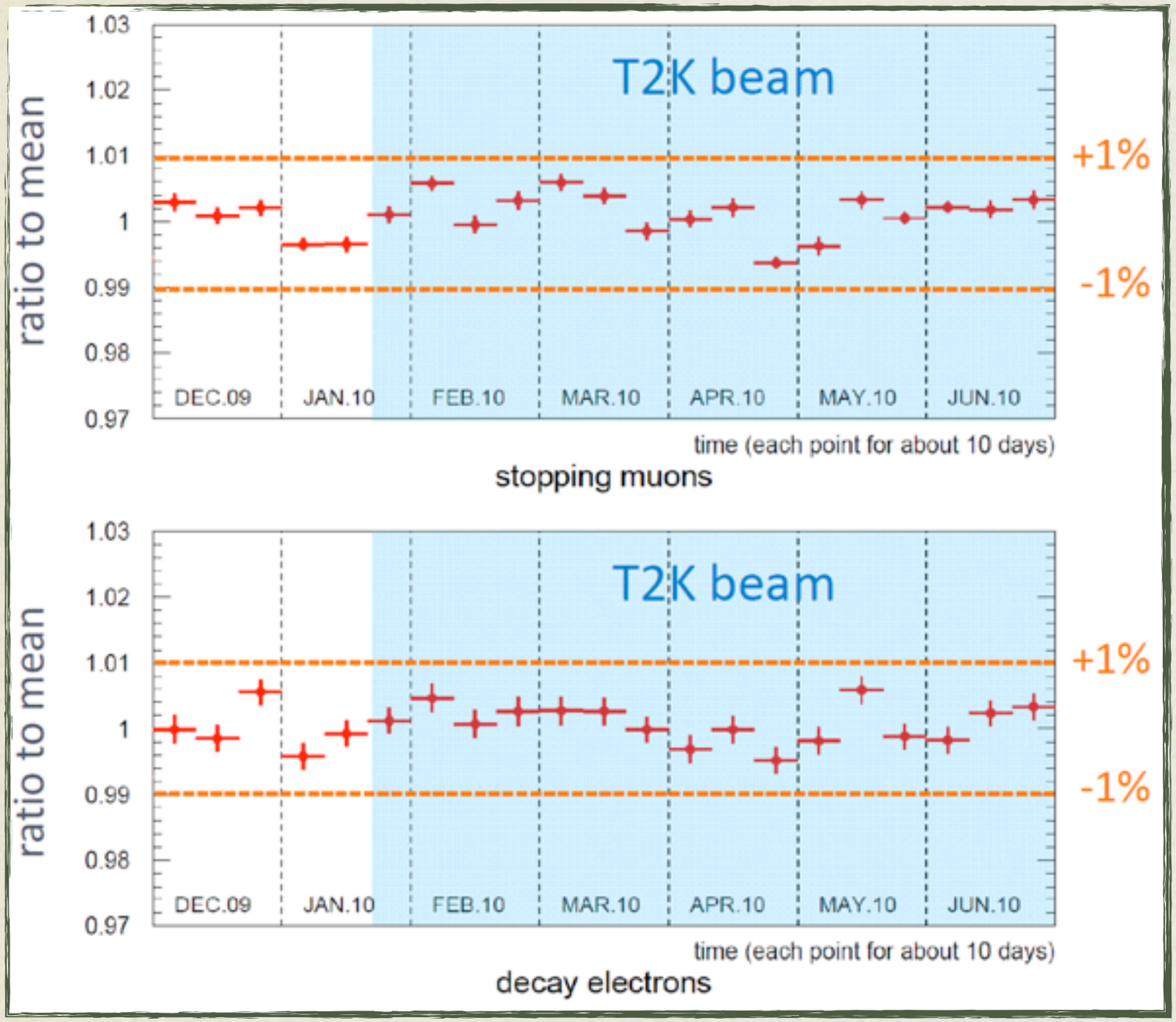
April 27th, 2010

Multi ring mu-like

P_μ= 1438 MeV/c -- 2 decay electrons

June 19th, 2010

Energy scale stability



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

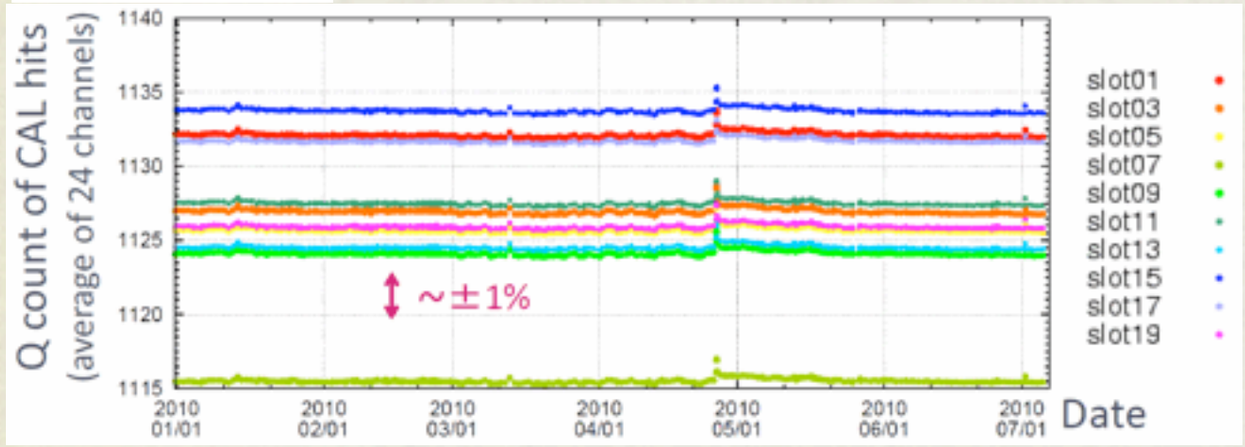
Measured with off-beam time cosmics.

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

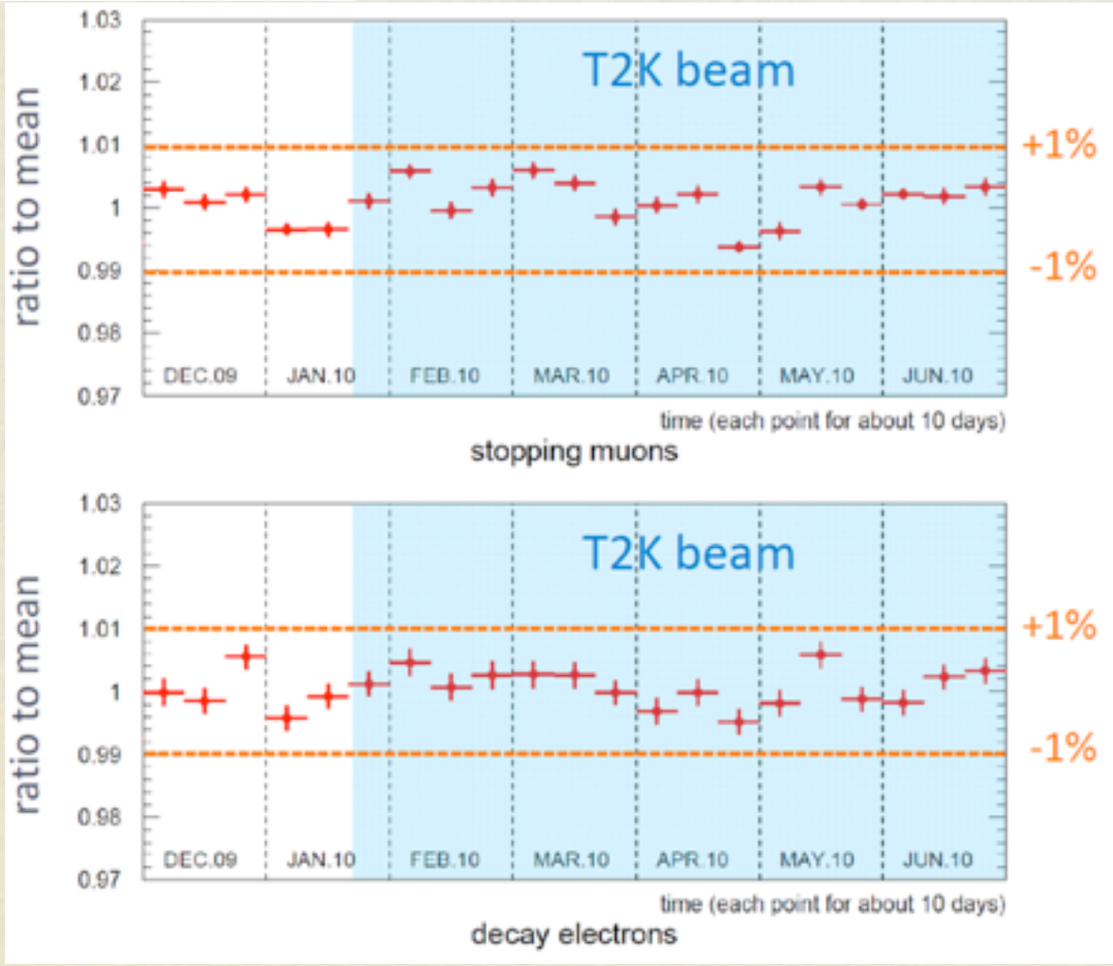
Very stable energy scale during T2K running period

SK stability

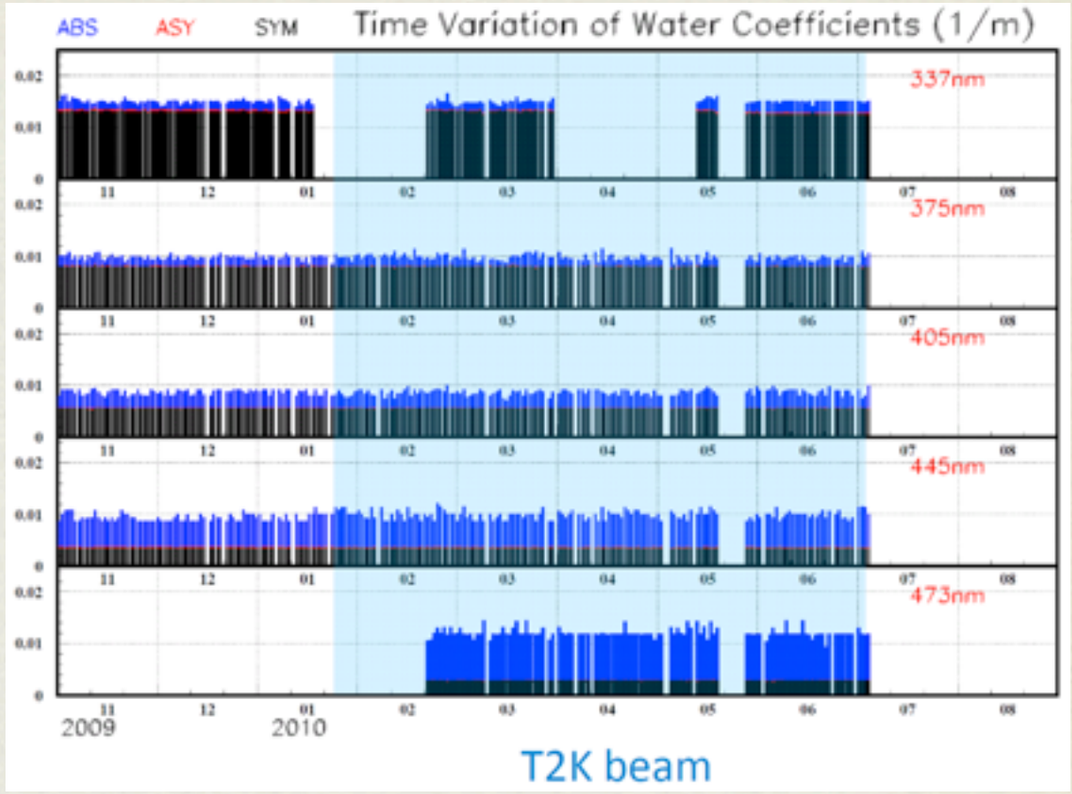
Electronics



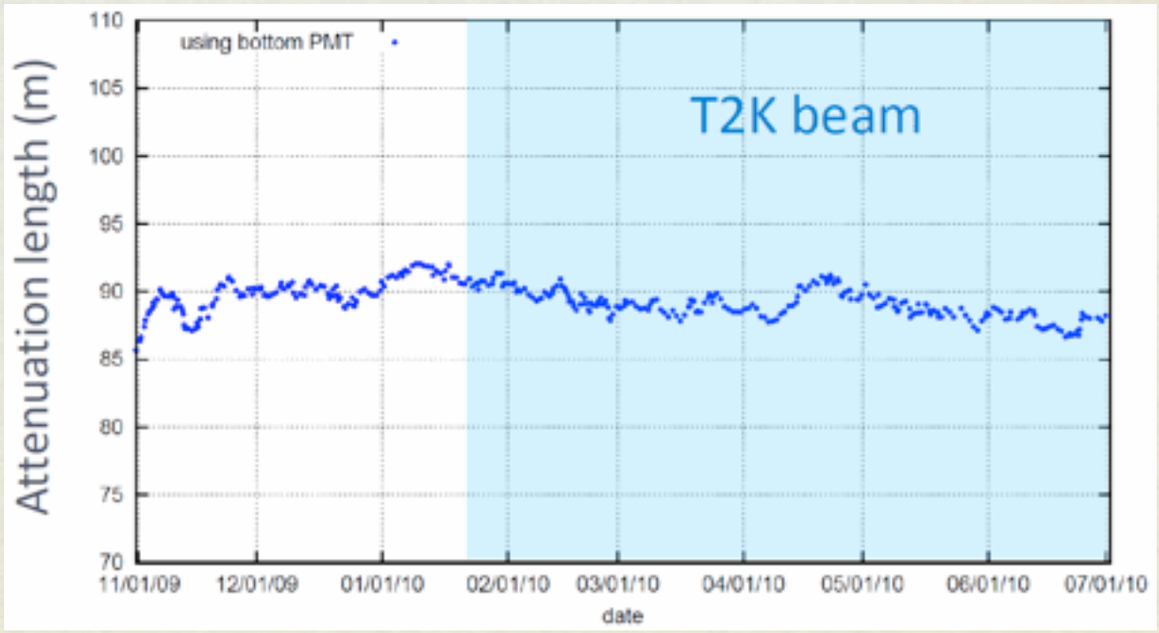
Energy scale



water scattering



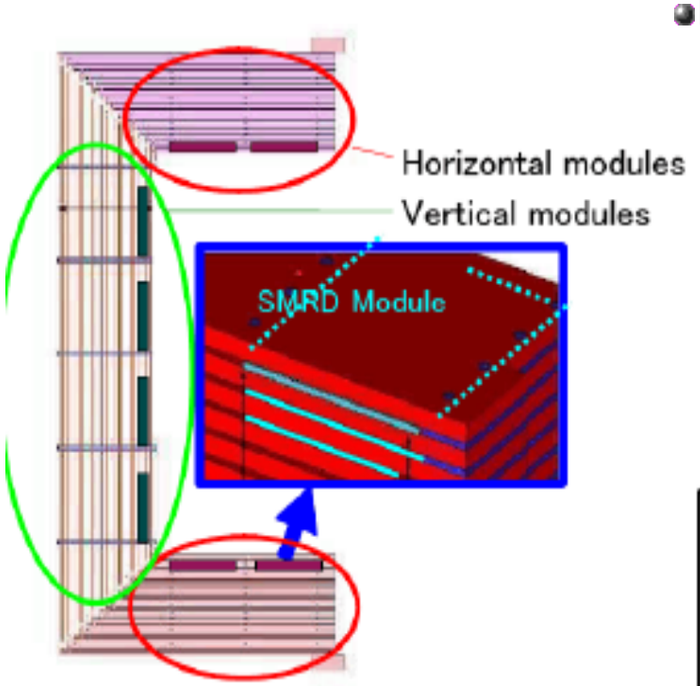
water transparency



SMRD: Side muon range detector

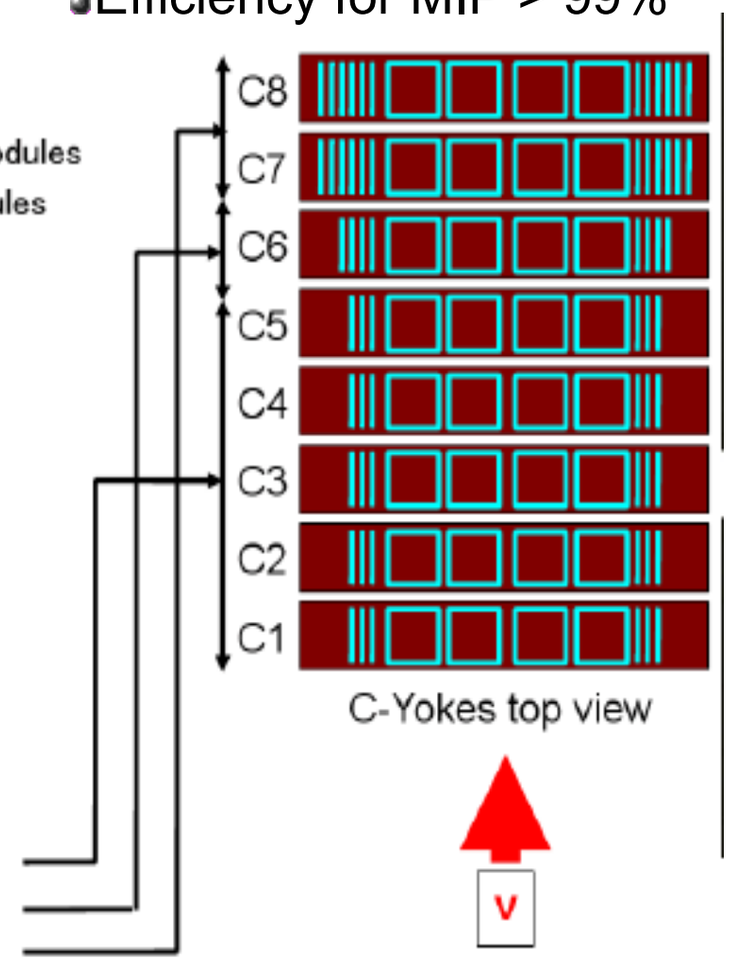
Side Muon Range Detector:

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

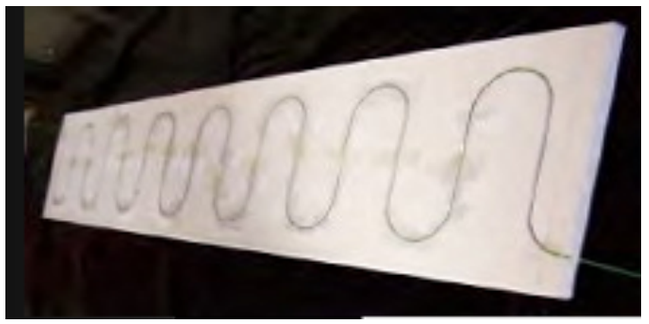


Horizontal modules: 192 modules,
3 layers for all C-yokes.

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)



SMRD

Upgrade plan