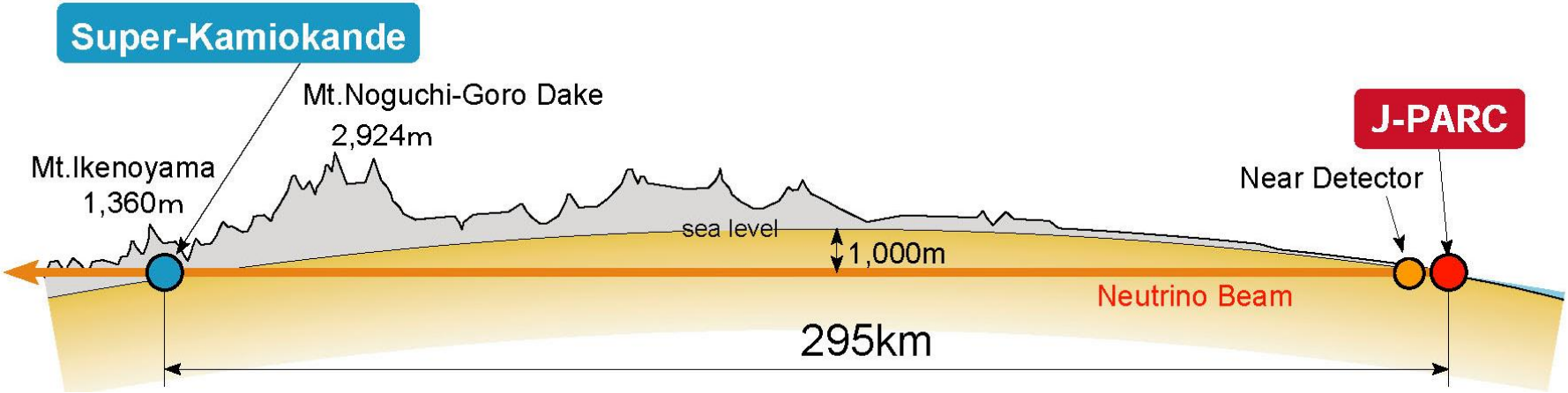

The T2K Experiment

Stefan Roth
Physics Institute III B
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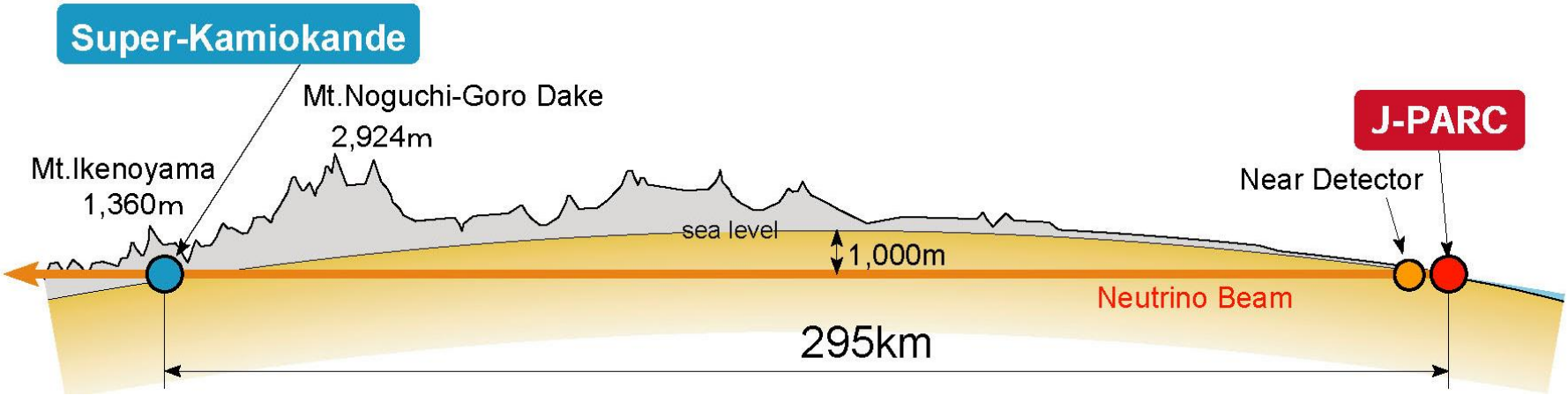
Physics Institute III B

RWTH AACHEN UNIVERSITY

Contents

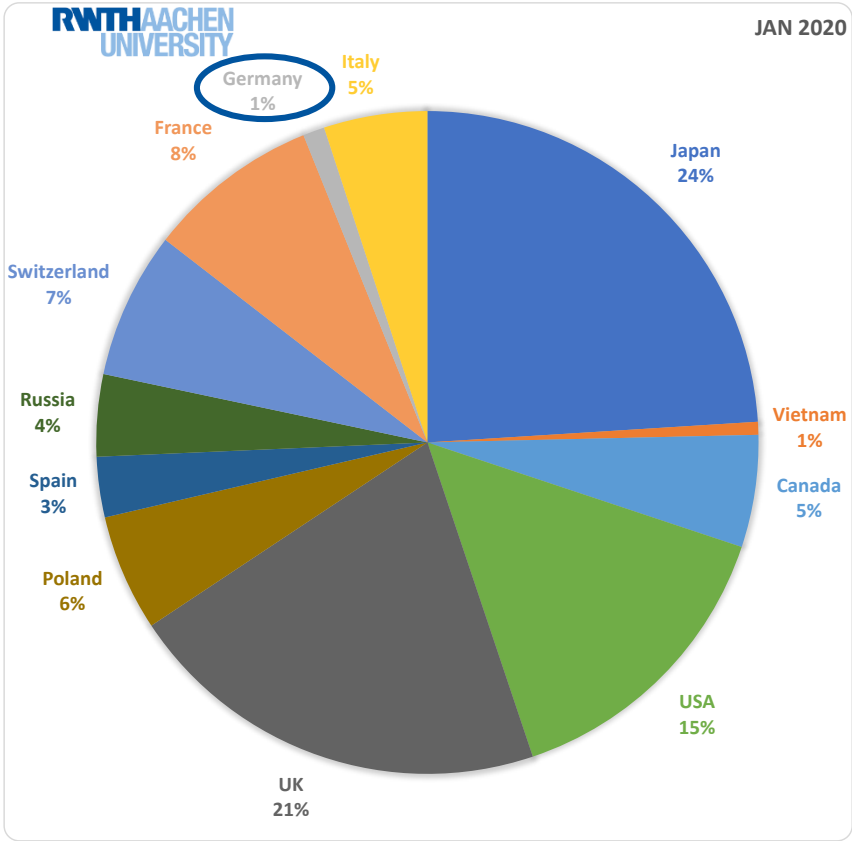
- **Collaboration and Experiment**
- **Recent Result on CP violation**
- **Future Prospects**

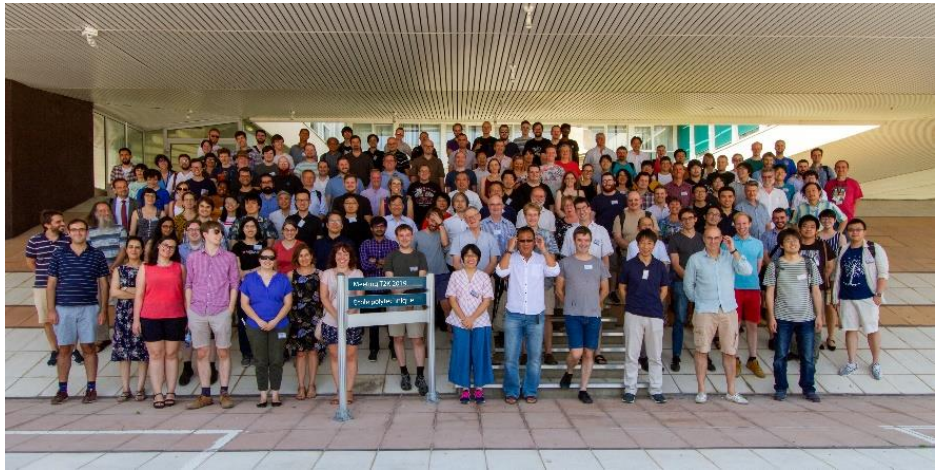


Collaboration and Experiment

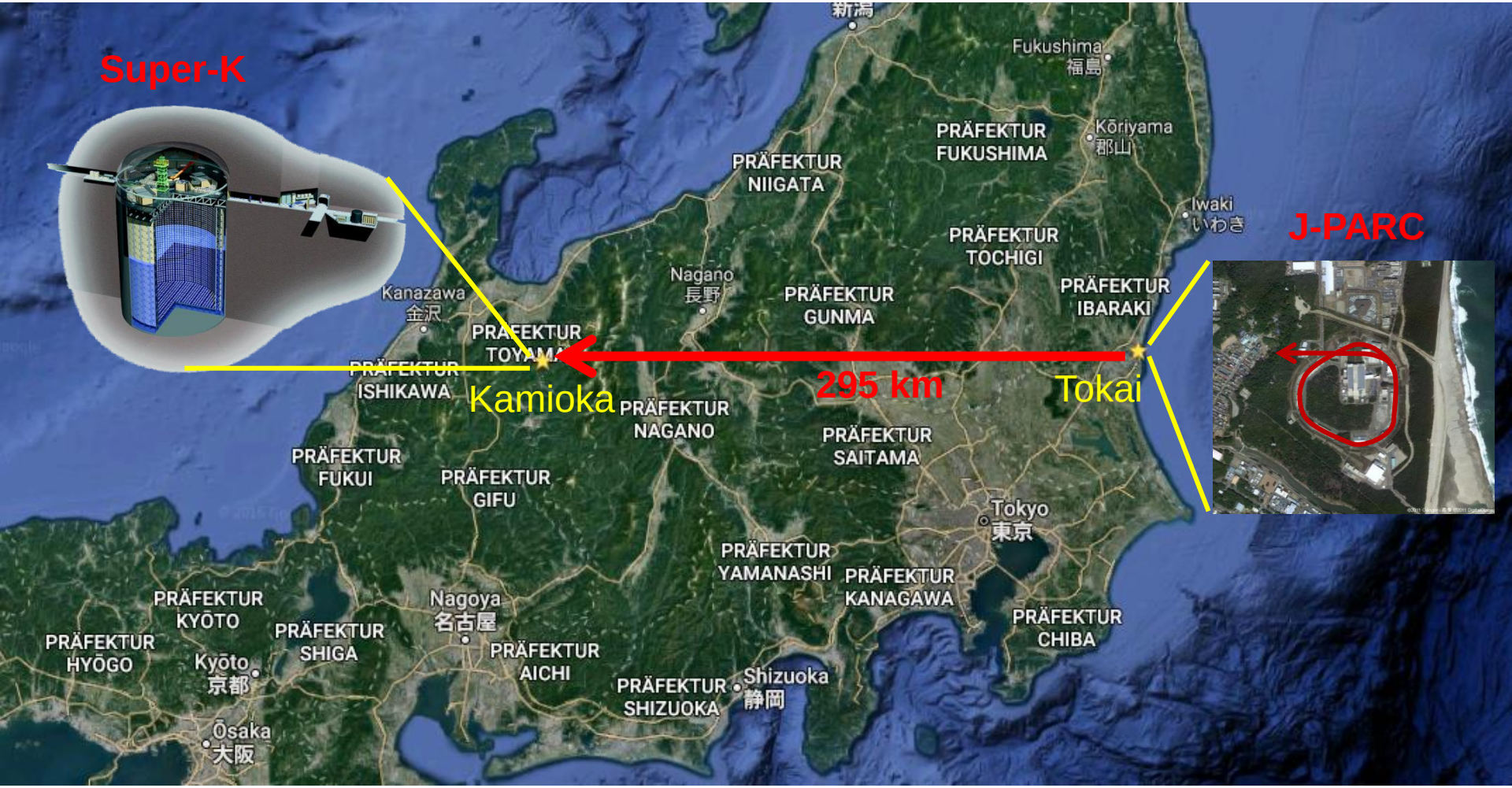
The T2K Collaboration

500 scientists from 69 institutions in 12 countries

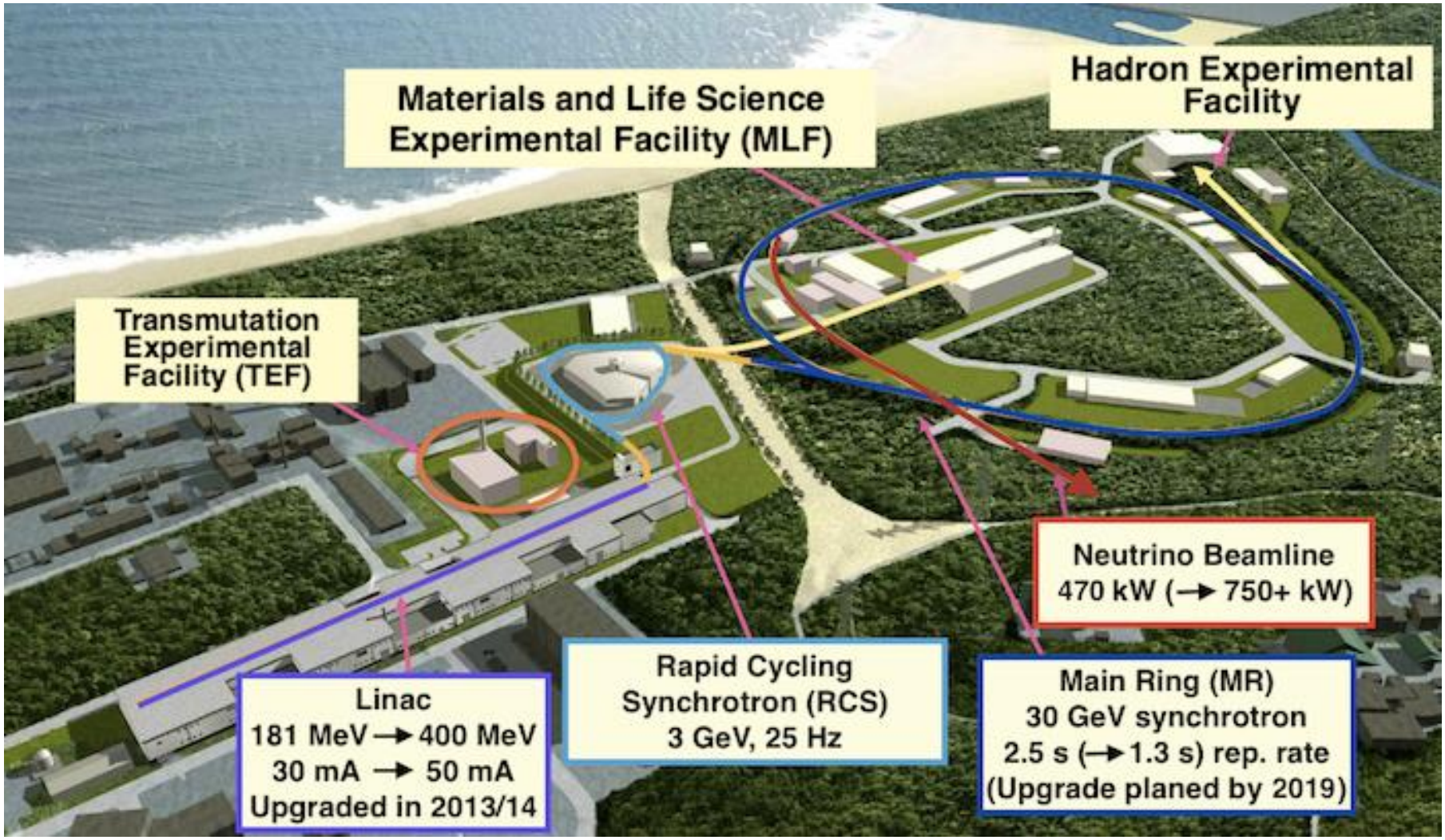




The neutrino oscillation experiment Tokai to Kamioka (T2K)

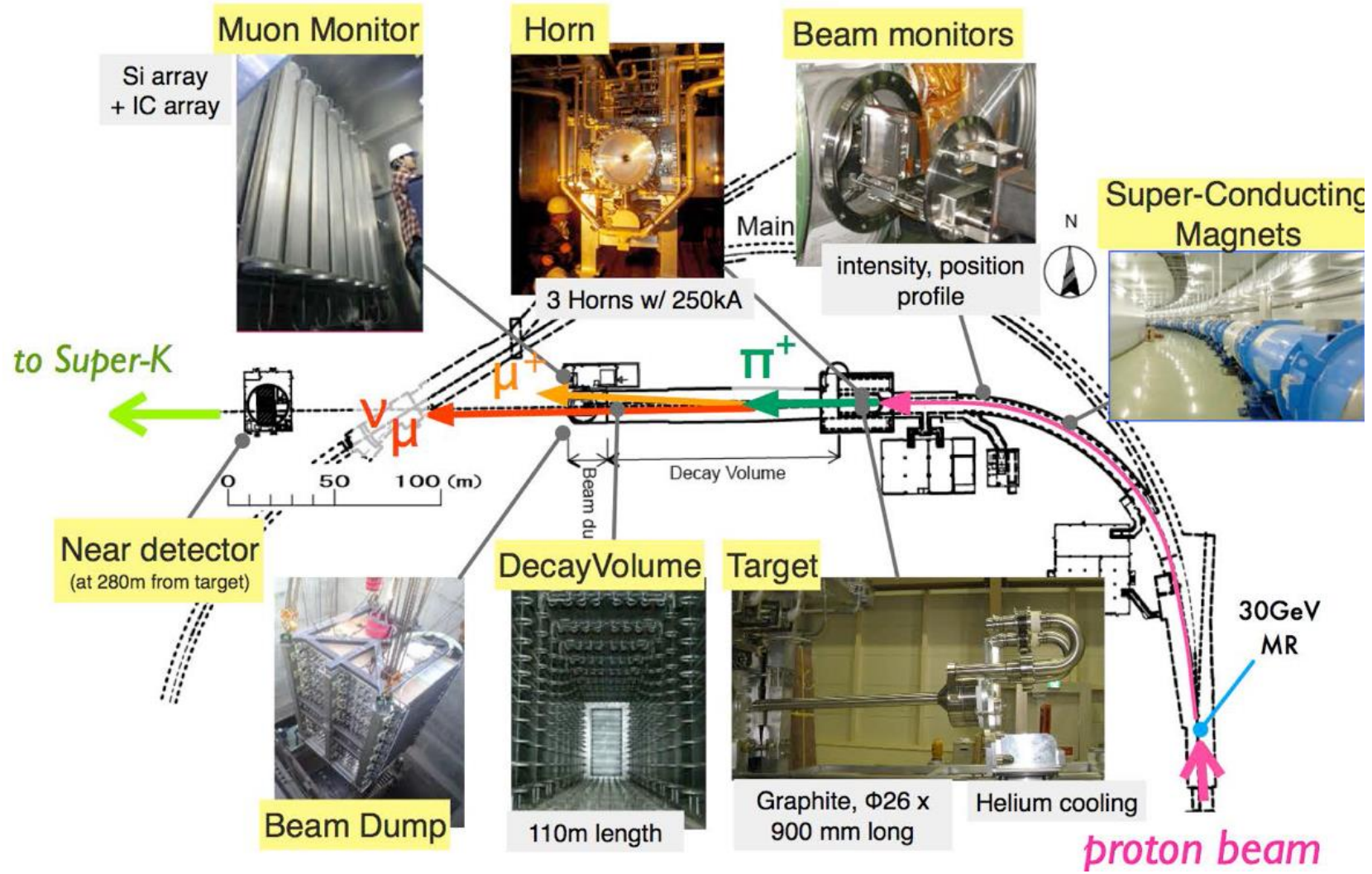


Japan Proton Accelerator Research Complex

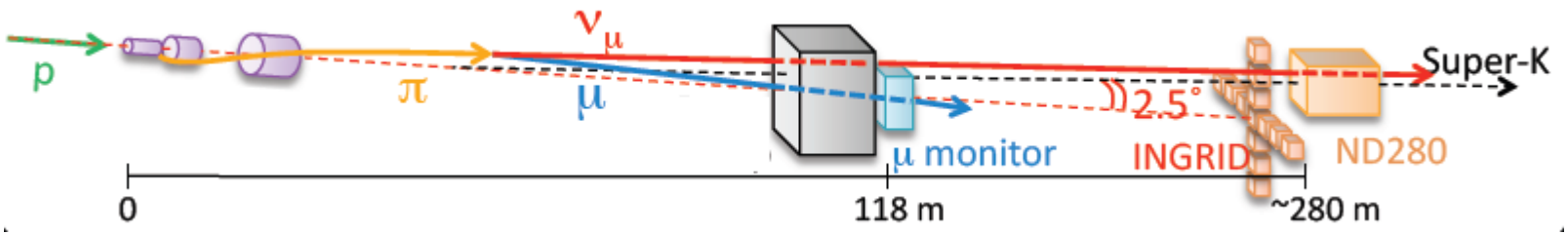


The Neutrino Beam

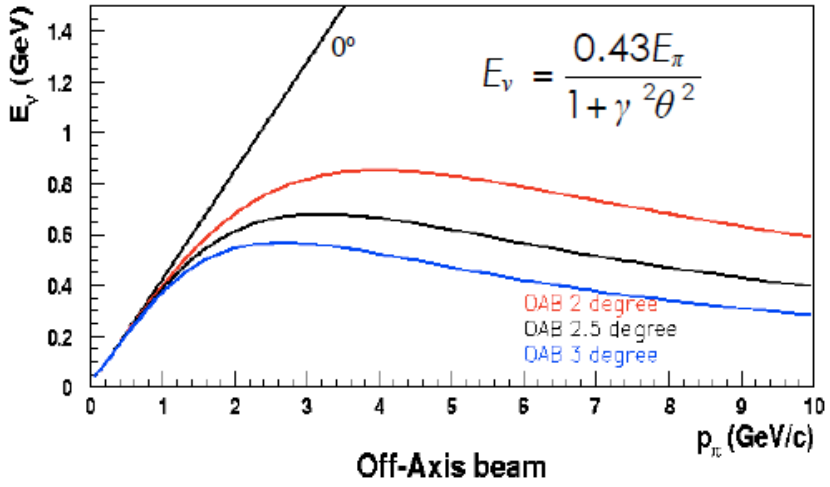
30 GeV proton beam on carbon target
Beam intensity at 515 kW
Up to now $3 \cdot 10^{21}$ protons on target (POT)

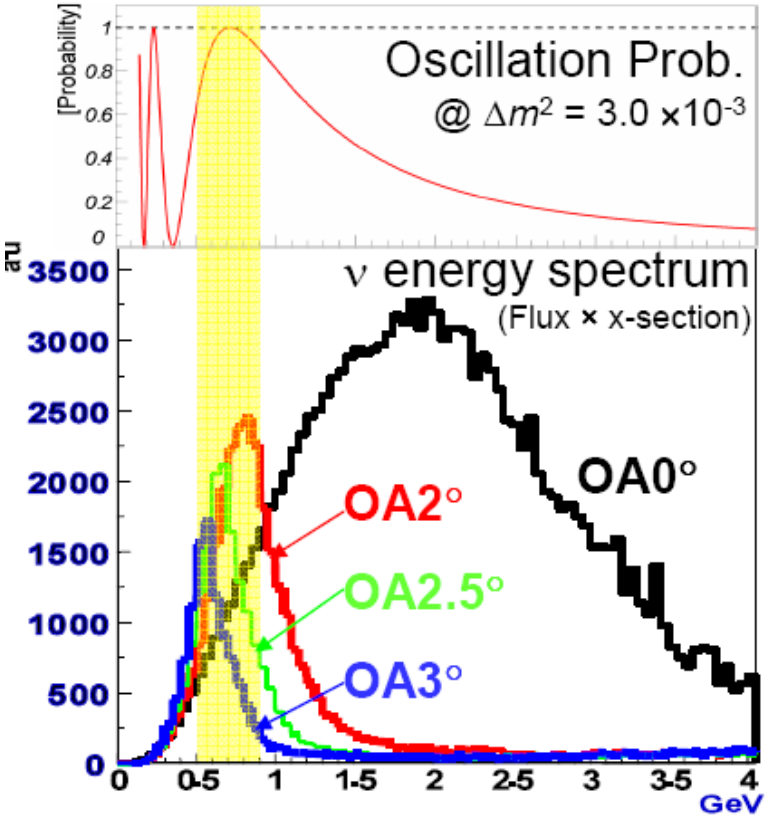


Off-Axis Neutrino Beam



- Use neutrinos at 2.5º off-axis
- Intense narrow energy band
- Energy maximum tuned at oscillation maximum at ~ 0.6 GeV
- 1 mrad offset would give 2% energy shift





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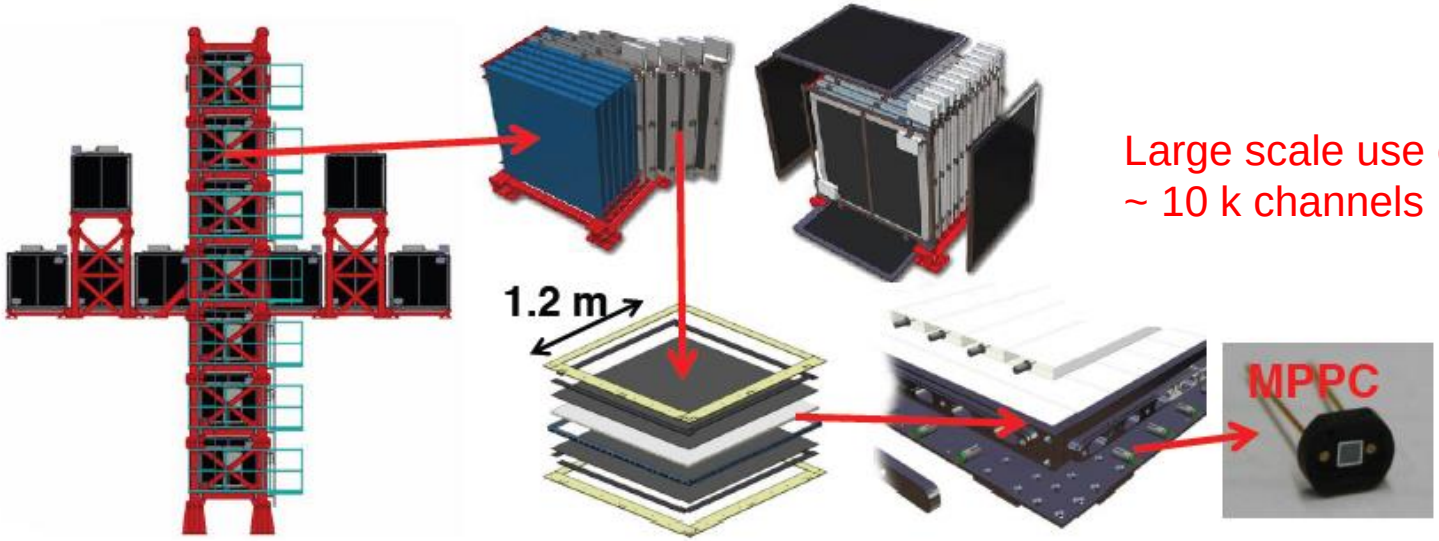
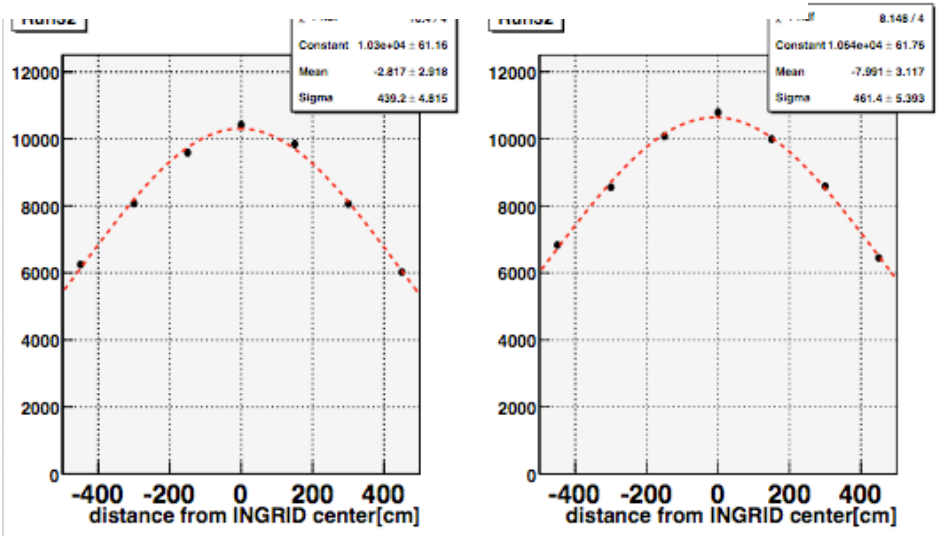
On axis: Interactive Neutrino Grid (INGRID)



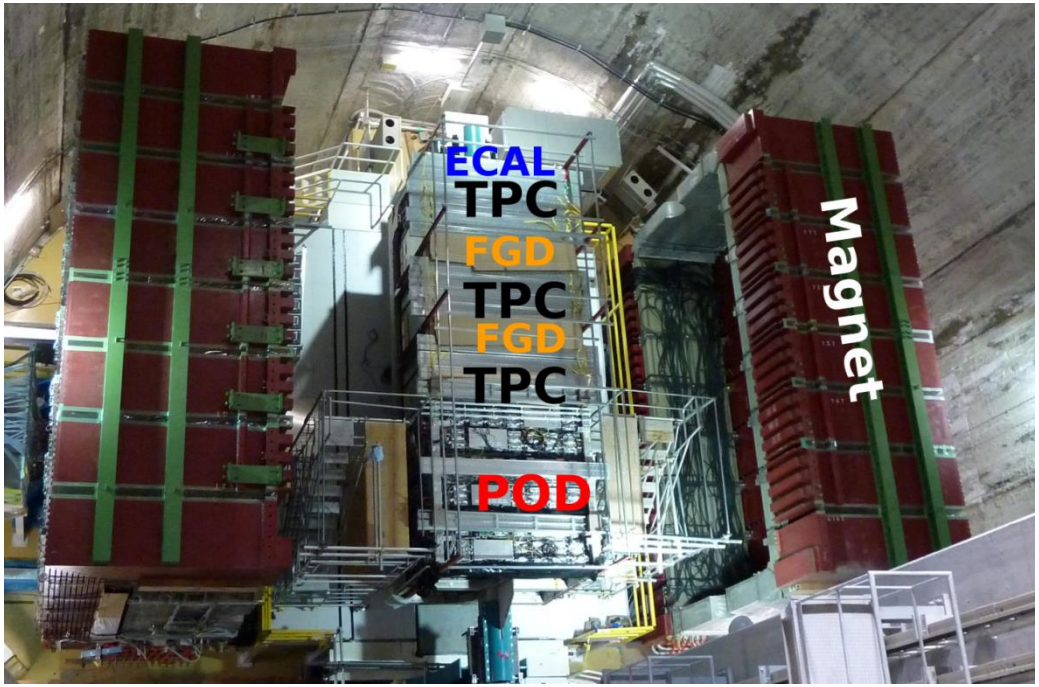
Large scale use of MPPC
~ 10 k channels !

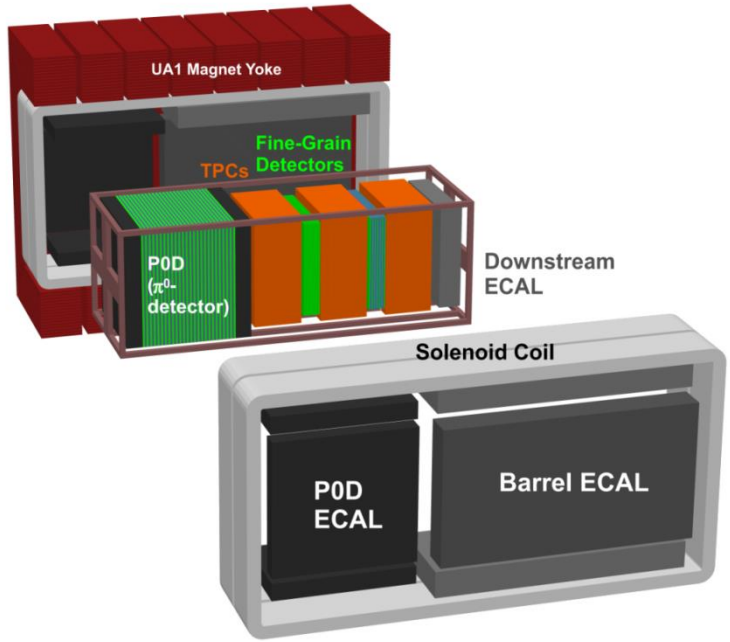
- 14 iron-scintillator modules
- arranged as crosshairs
- X-Y scintillator layers
- ~700 ν interactions/day @ 50 kW
- Determination of beam direction better than 1 mrad



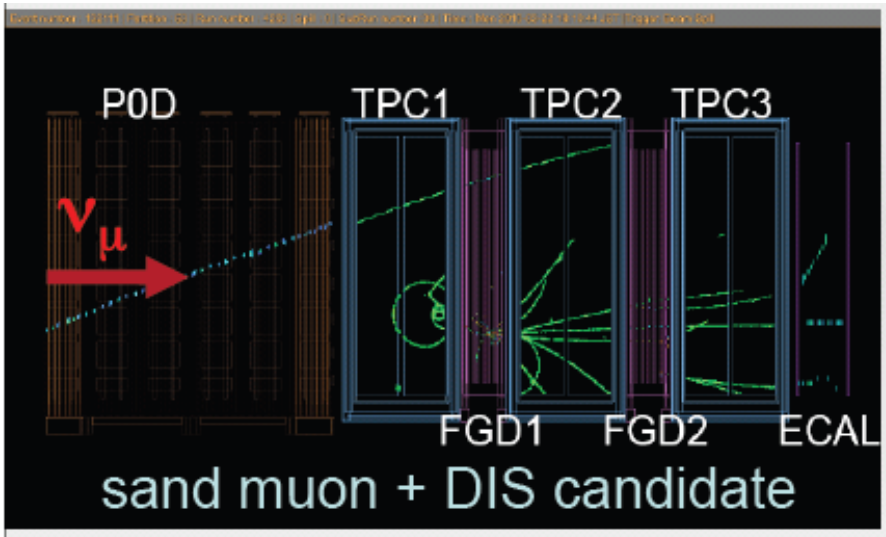
Off-Axis: Near detector ND280 (280 m from target)

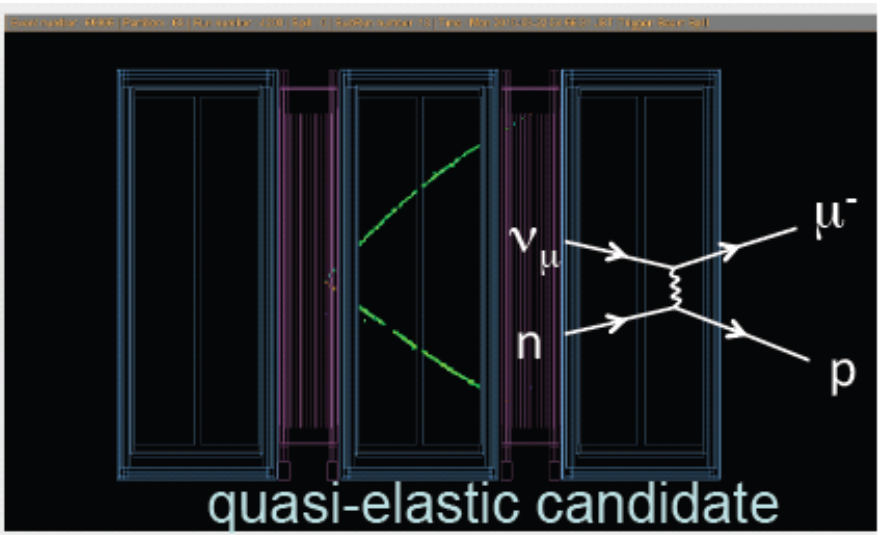
- Inside 0.2 T former UA1/NOMAD magnet
- The π^0 detector P0D (lead/water/scintillators)
- Barrel and downstream ECAL
- Fine Grain Detectors FGD (water/scintillators)
- Time Projection Chambers TPC (Micromegas readout)

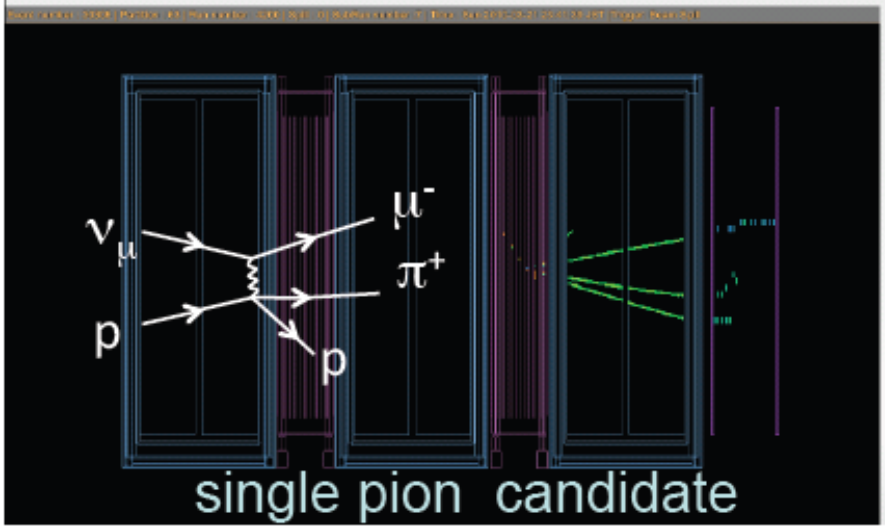


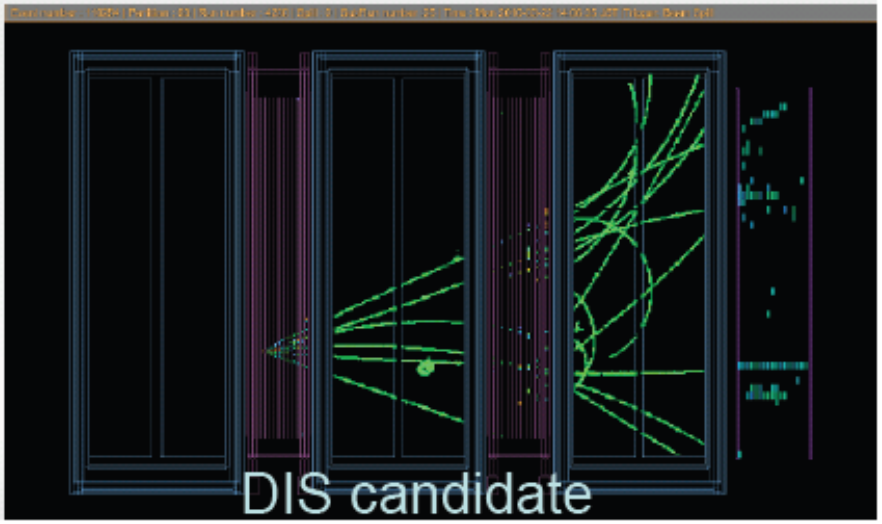


Neutrino Events in ND280

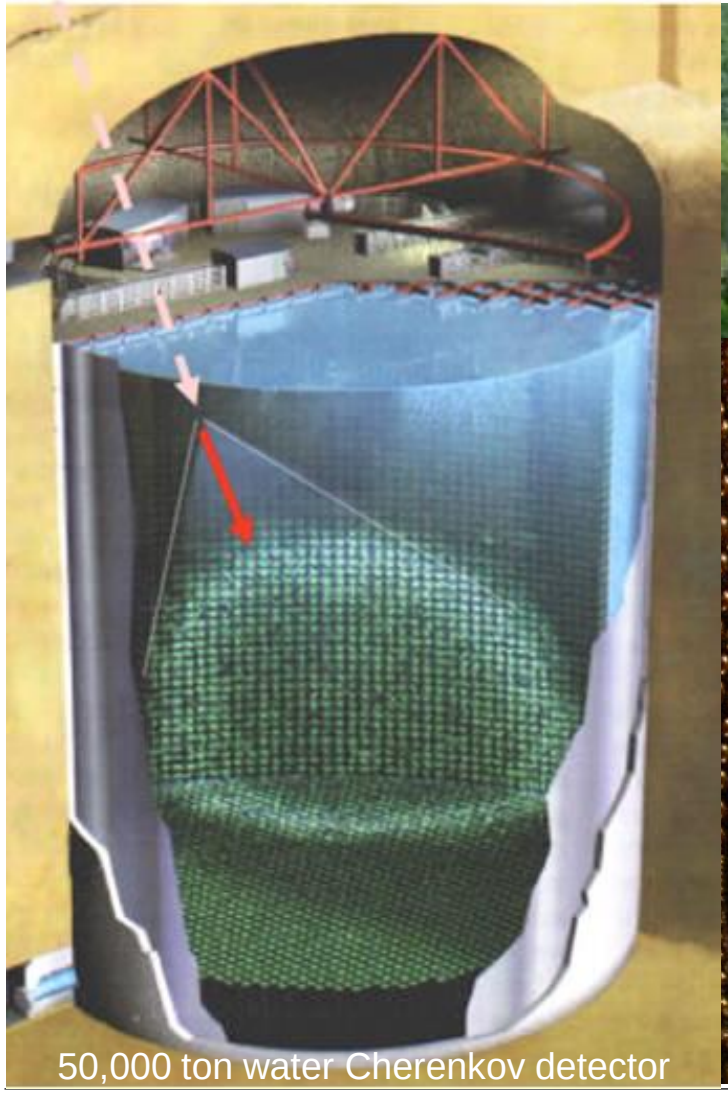


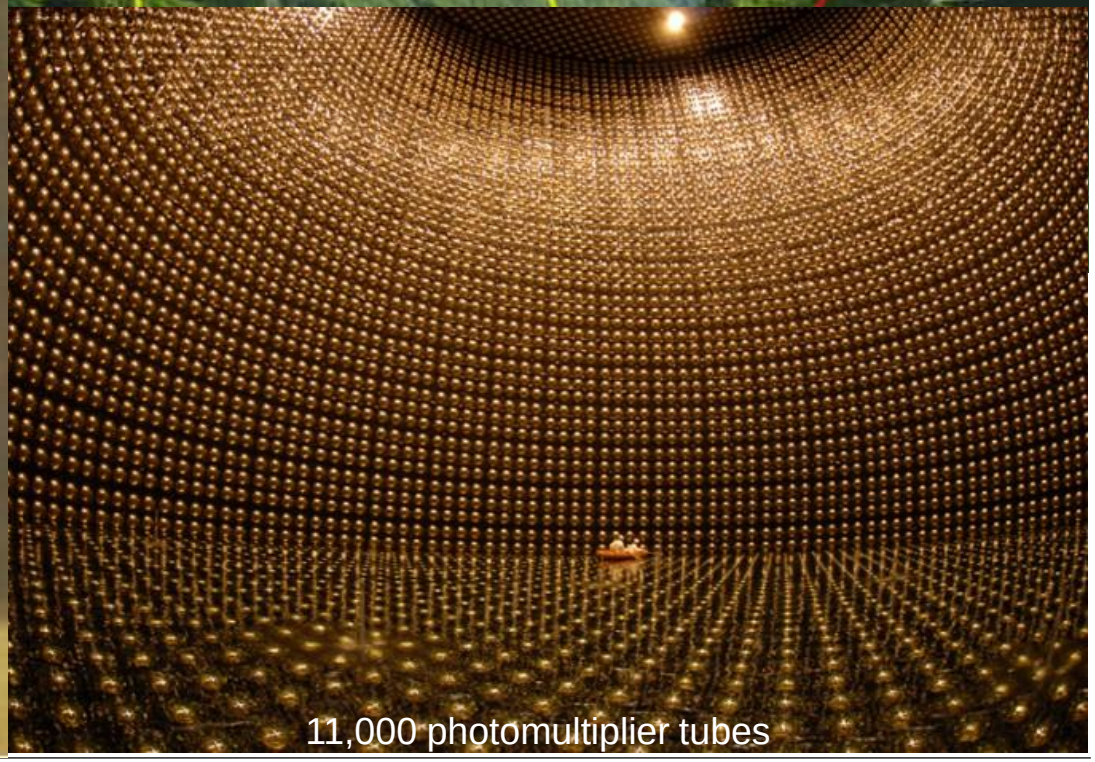






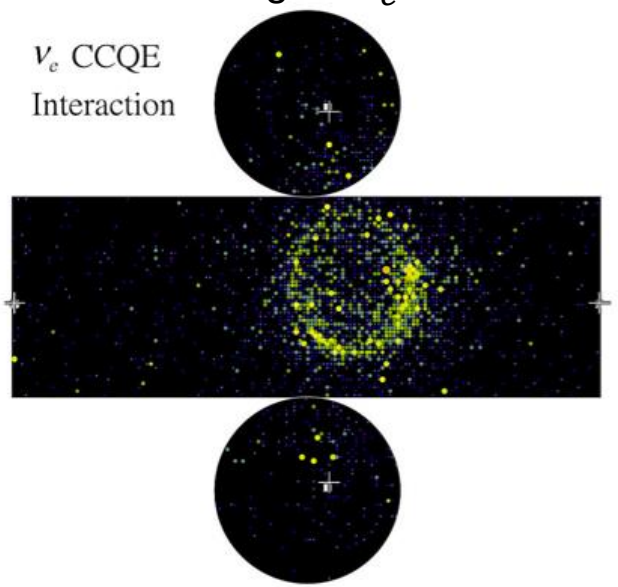
Super-Kamiokande

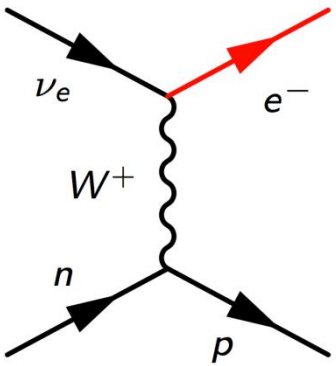




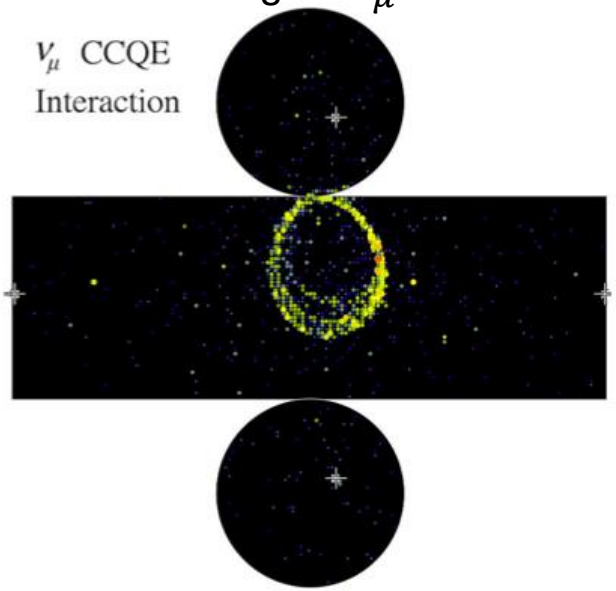
Typical Interactions

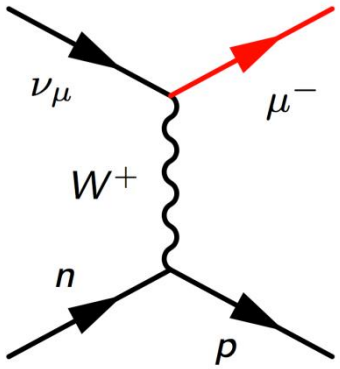
Signal ν_e



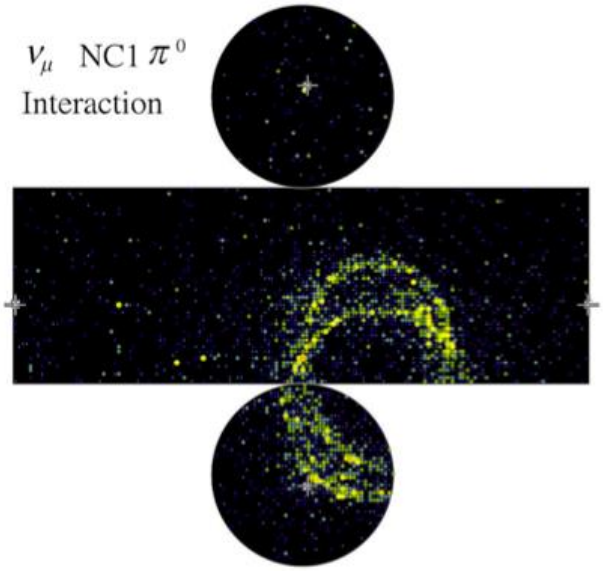


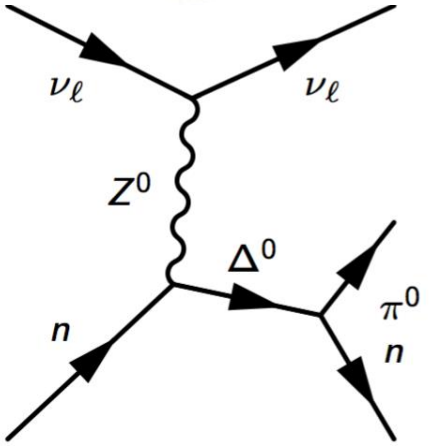
Signal ν_μ



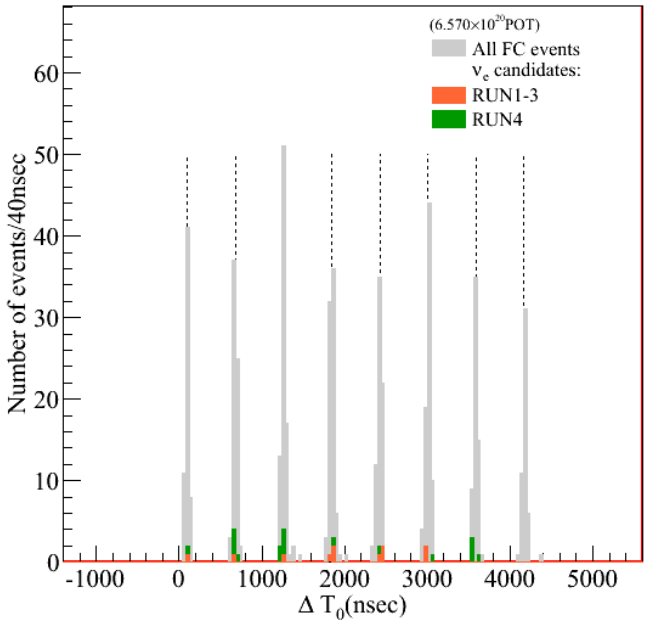


Background

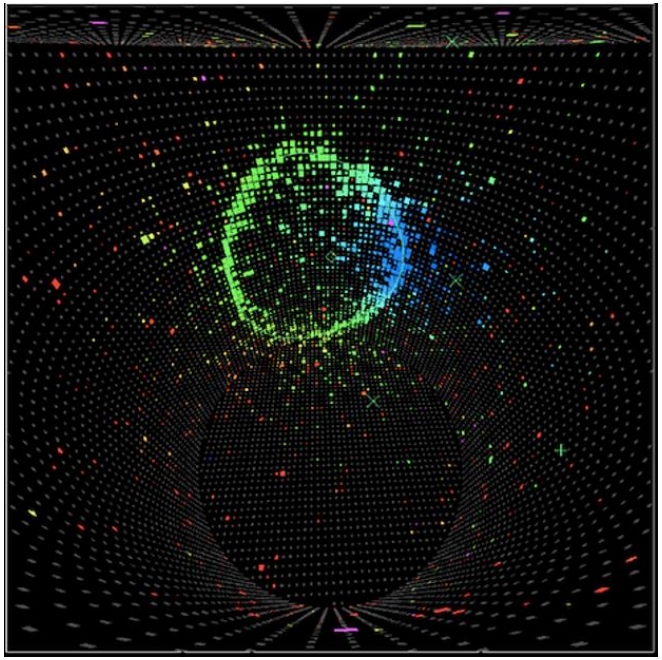




First Detection of Electron Neutrino Appearance



Electron Neutrino!



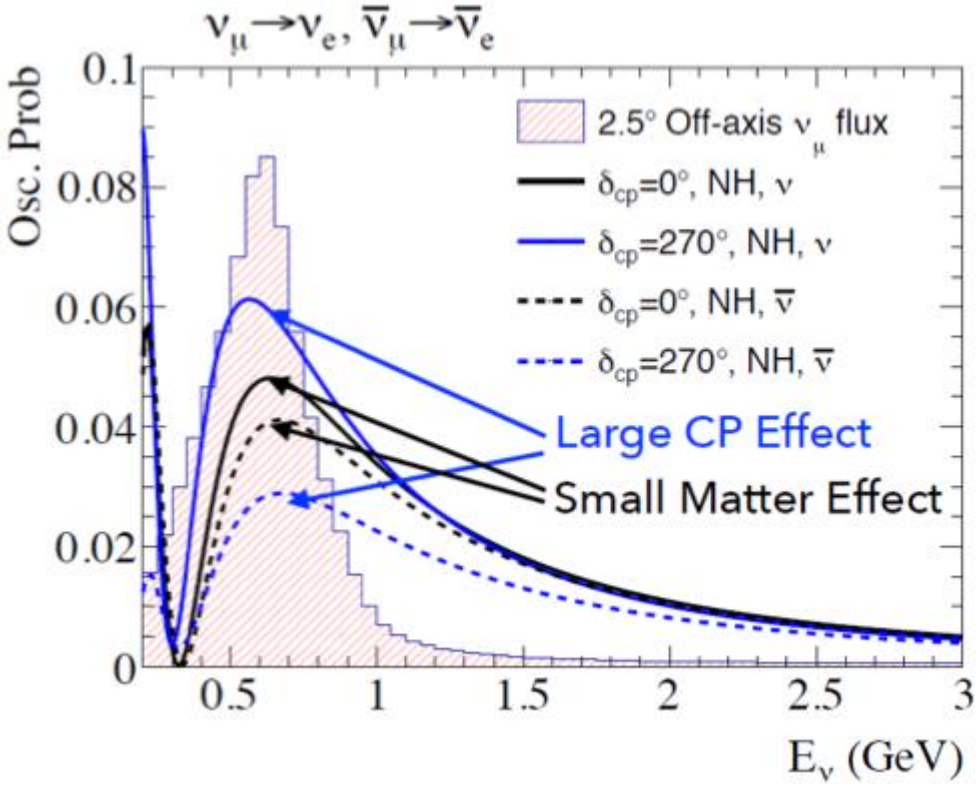
For the first time neutrinos have actively been seen to change from one flavour to another rather than just viewing a disappearance. The T2K experiment has seen muon neutrinos change character to become electron neutrinos after a journey of 295km across Japan. The certainty of this measurement is quoted as 7.5 standard deviations from zero or to put in terms of percentage over 99.9999999999936% sure that the appearance is occurring.

19 July 2013

theguardian

Recent Result on CP violation

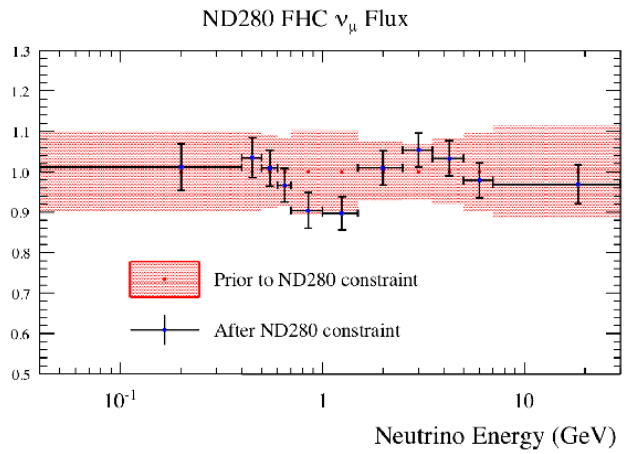
Next Step: Quest after CP Violation

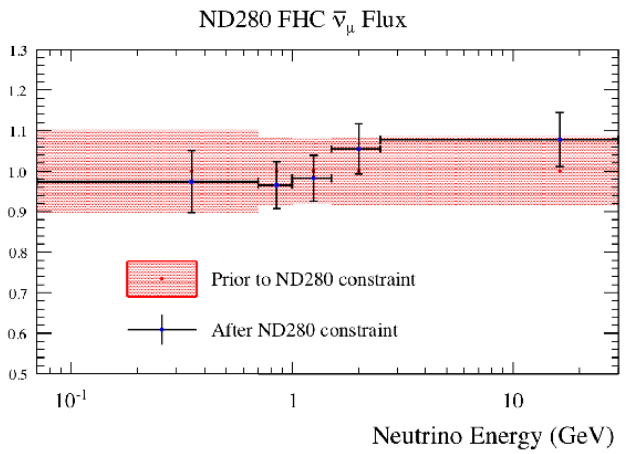


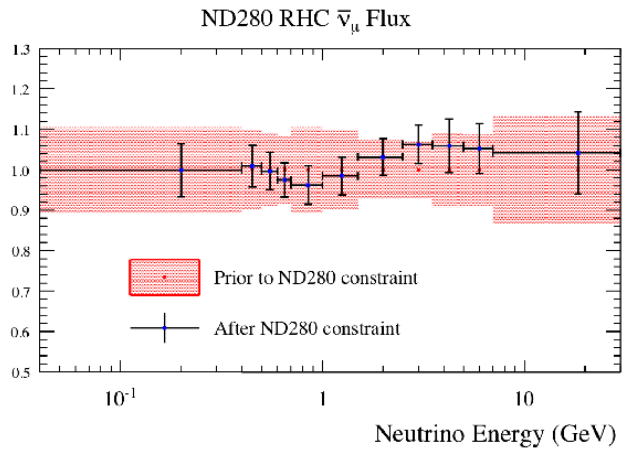
$\delta_{CP} = +\pi/2 = 90° \Rightarrow$ minimize $P(\nu_\mu \rightarrow \nu_e)$ and maximize $P(\bar{\nu}_\mu \rightarrow \bar{\nu}_e)$

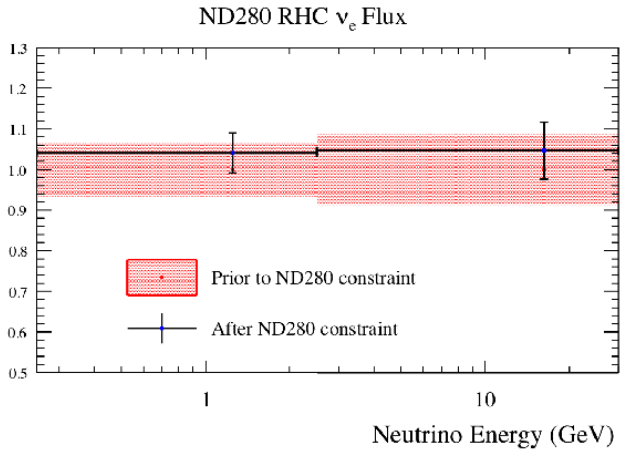
$\delta_{CP} = -\pi/2 = 270° \Rightarrow$ maximize $P(\nu_\mu \rightarrow \nu_e)$ and minimize $P(\bar{\nu}_\mu \rightarrow \bar{\nu}_e)$

Flux Constraints by Near Detector

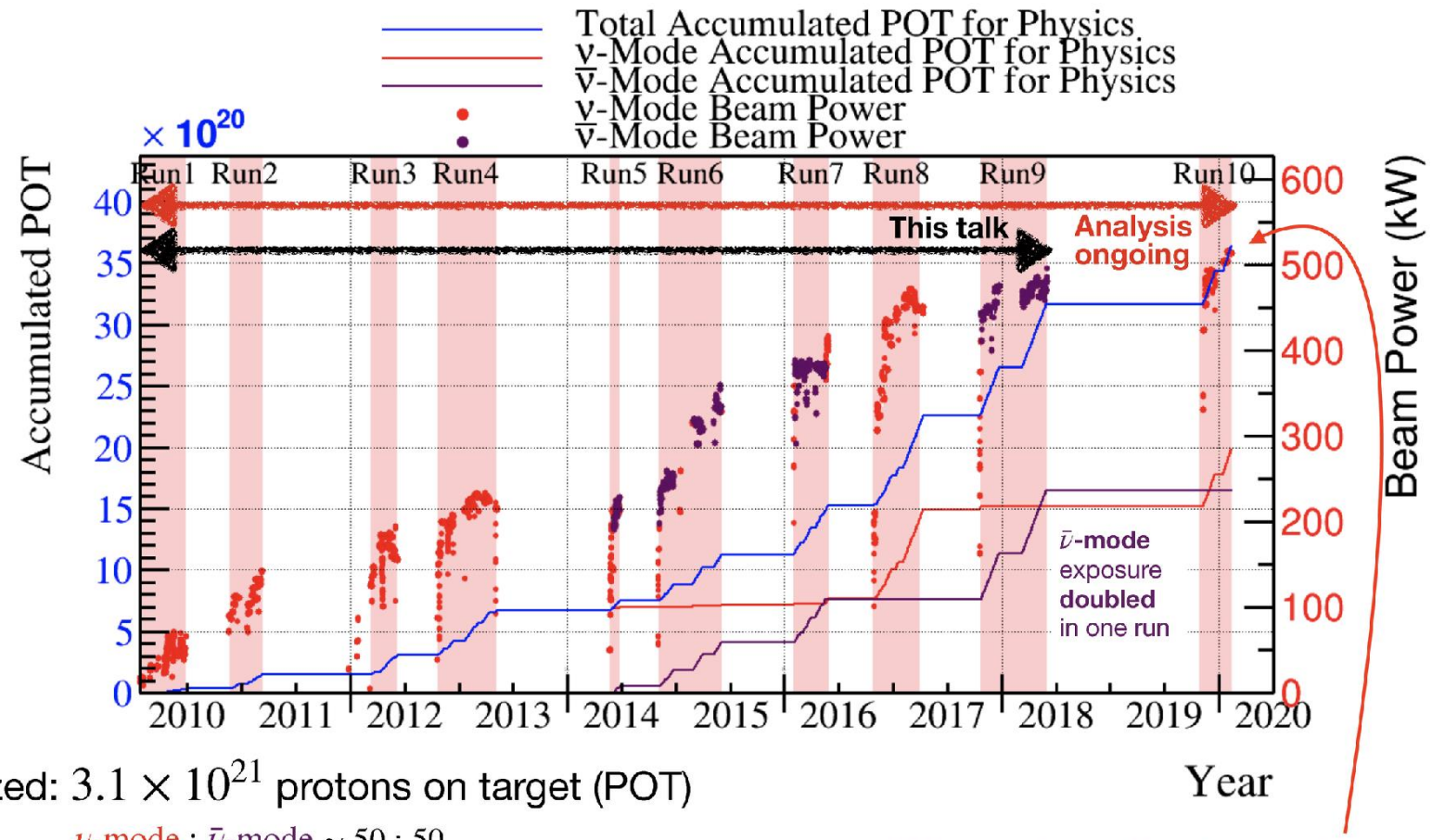








Protons on Target



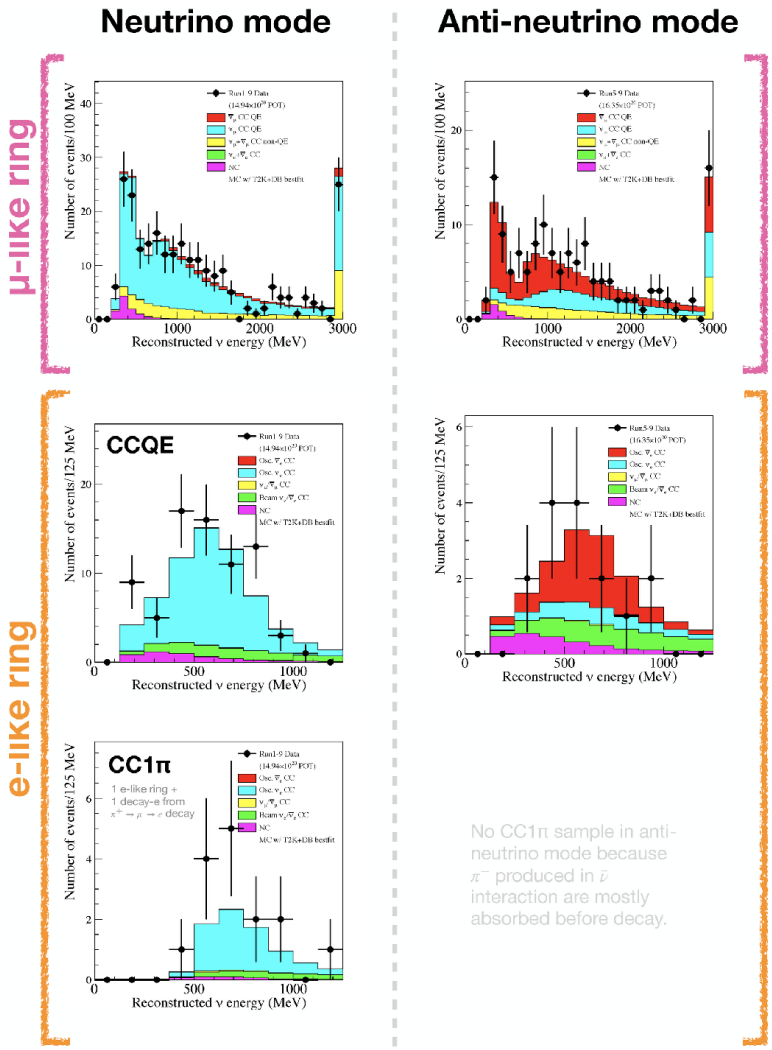
Analyzed: 3.1×10^{21} protons on target (POT)

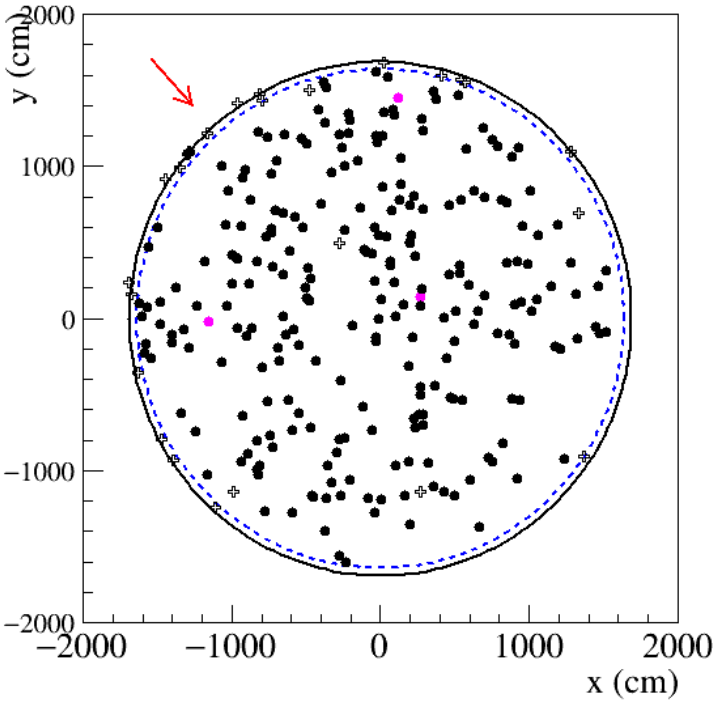
ν-mode : $\bar{\nu}$-mode $\sim$ 50 : 50

515 kW operation achieved recently!

33% increase of ν-mode data in upcoming analysis.

Super-K Data





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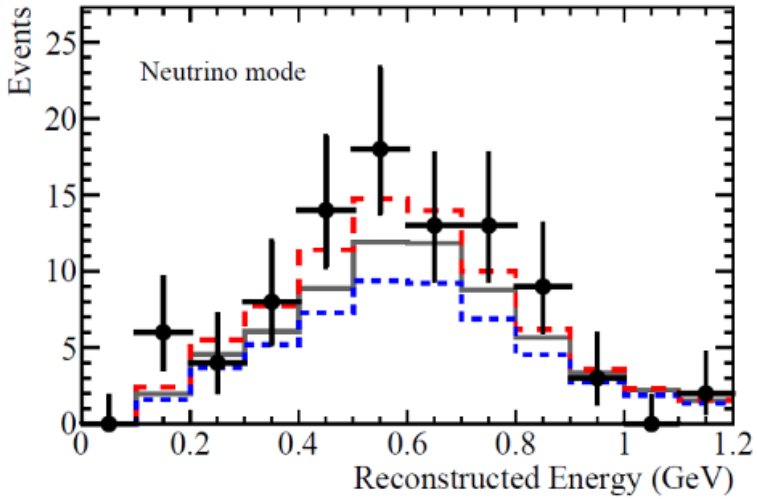
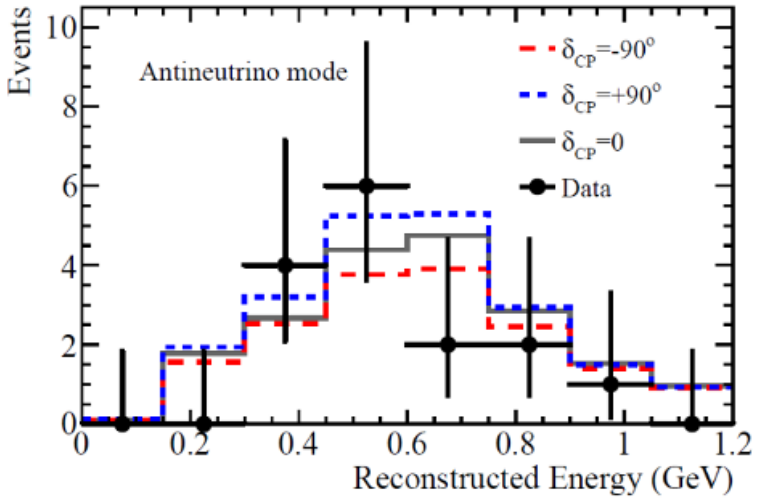
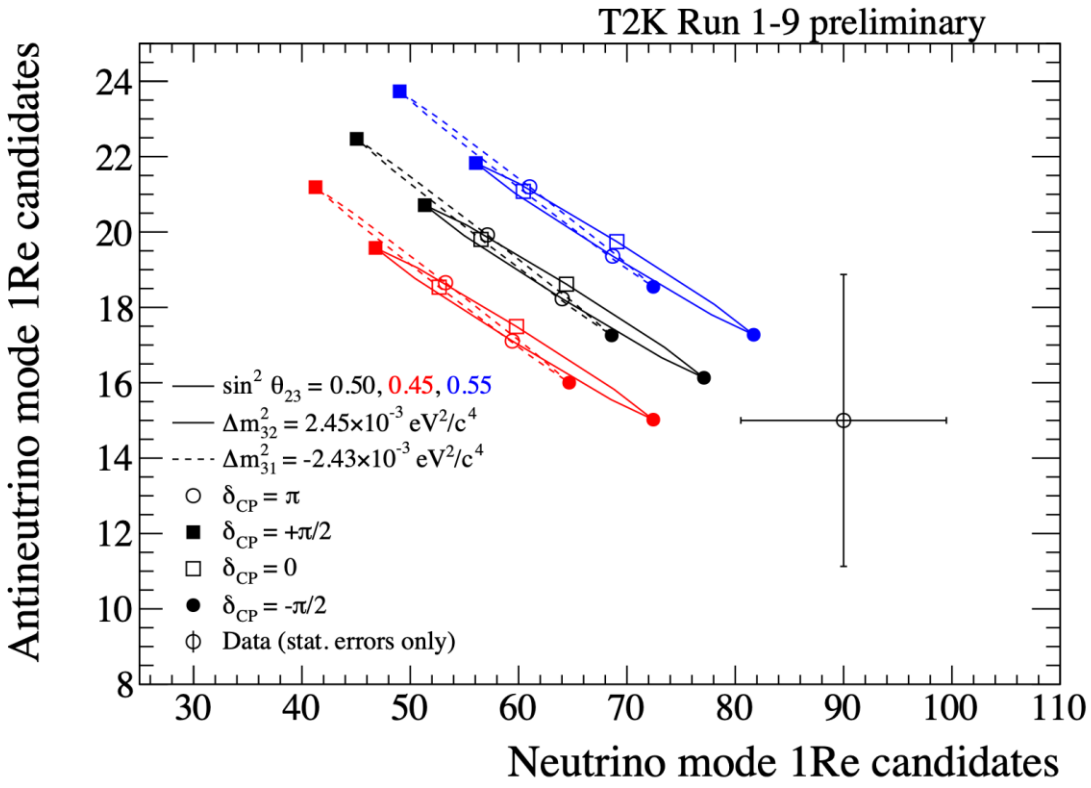
Comparison of Neutrino and Anti-Neutrino Data





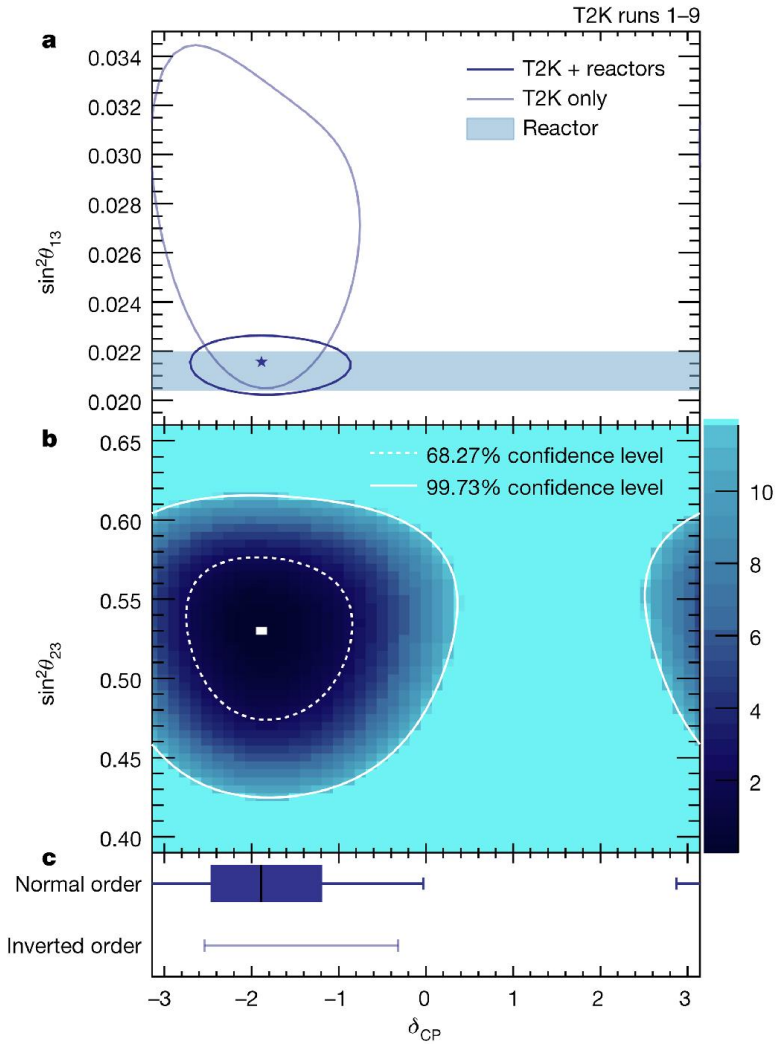
	Observed	Expectation	
		$\delta_{CP} = -90°$	$\delta_{CP} = +90°$
Electron neutrino	90	82	56
Electron antineutrino	15	17	22

Comparison with Theory



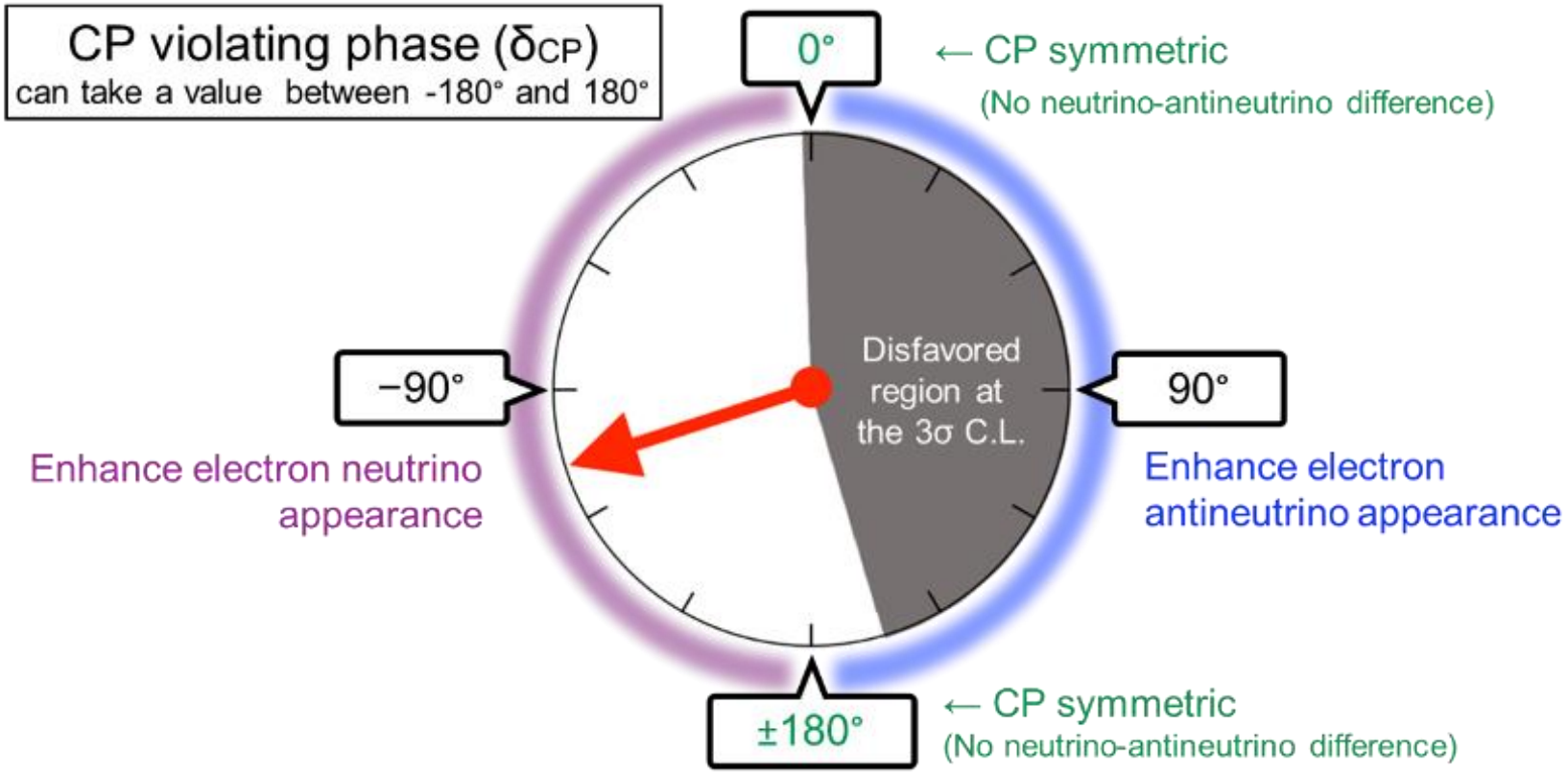
- More $\boldsymbol{\nu_e}$ events than expected
- Less $\overline{\boldsymbol{\nu}}_{\boldsymbol{e}}$ events than expected
- Data prefer large CP asymmetry with $\boldsymbol{\delta_{CP} = -\pi/2}$
- and normal hierarchy

Constraints on δ_{CP}

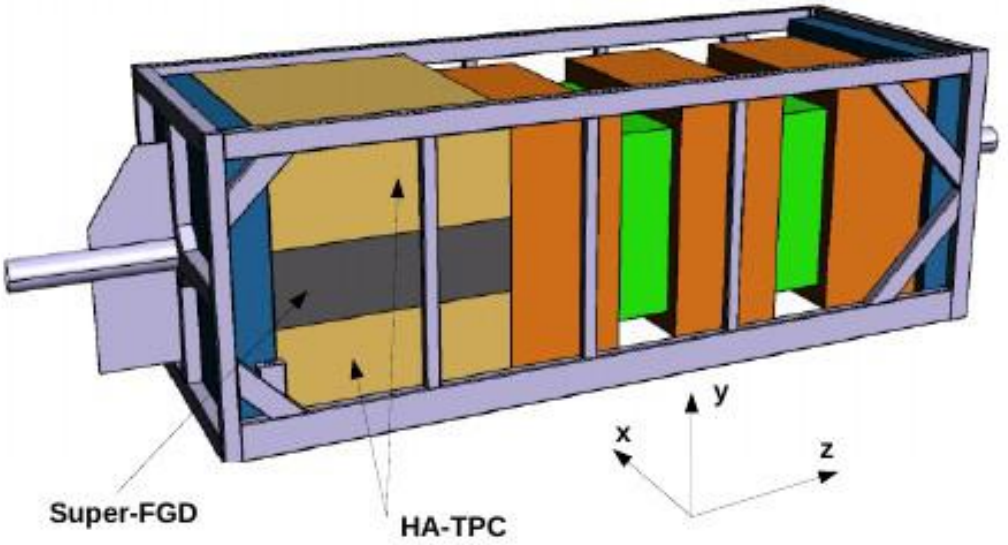


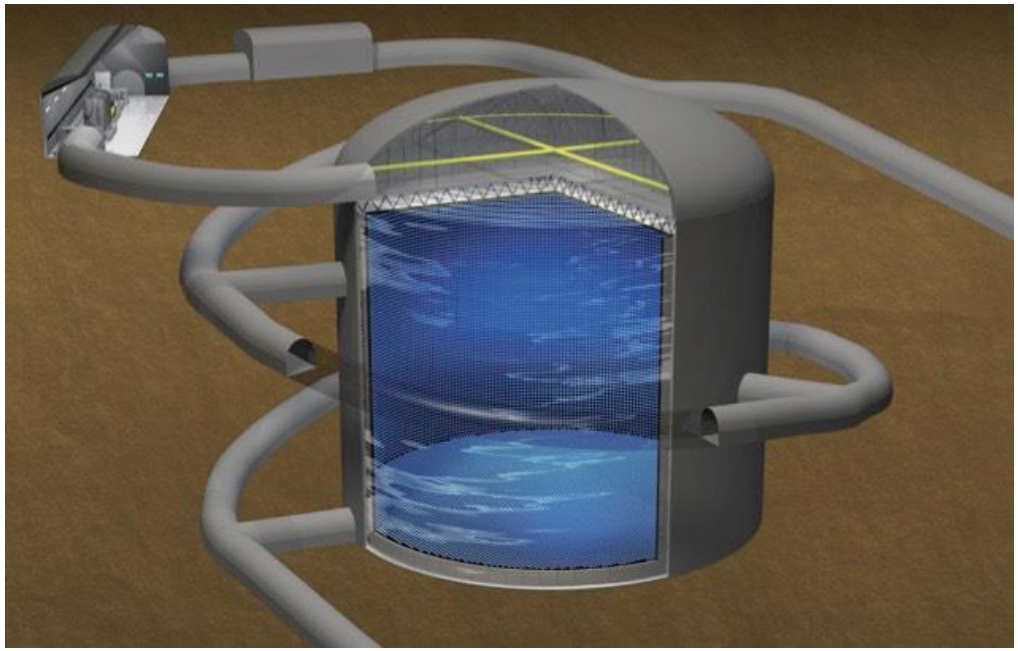
- Fit uses $\boldsymbol{\theta_{13}}$ from reactor neutrino experiments
- Fit constraints $\boldsymbol{\delta_{CP}}$
- Fit also prefers normal hierarchy

Constraints on δ_{CP}

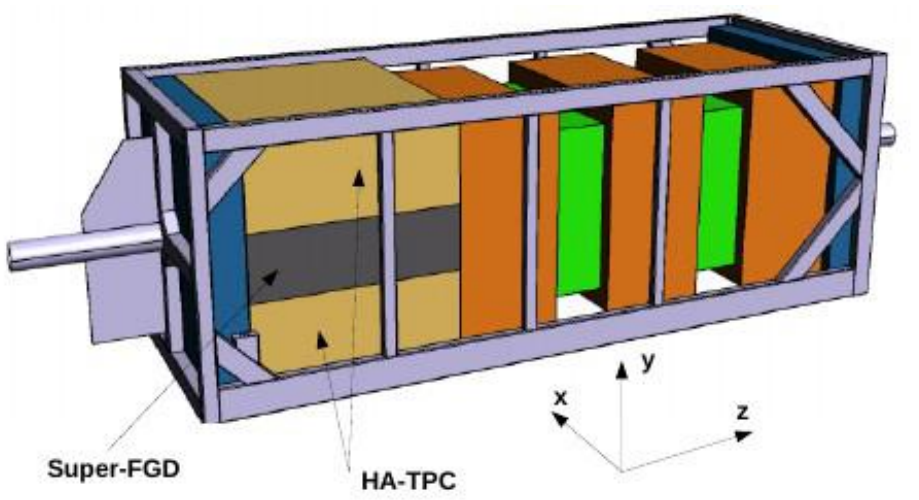


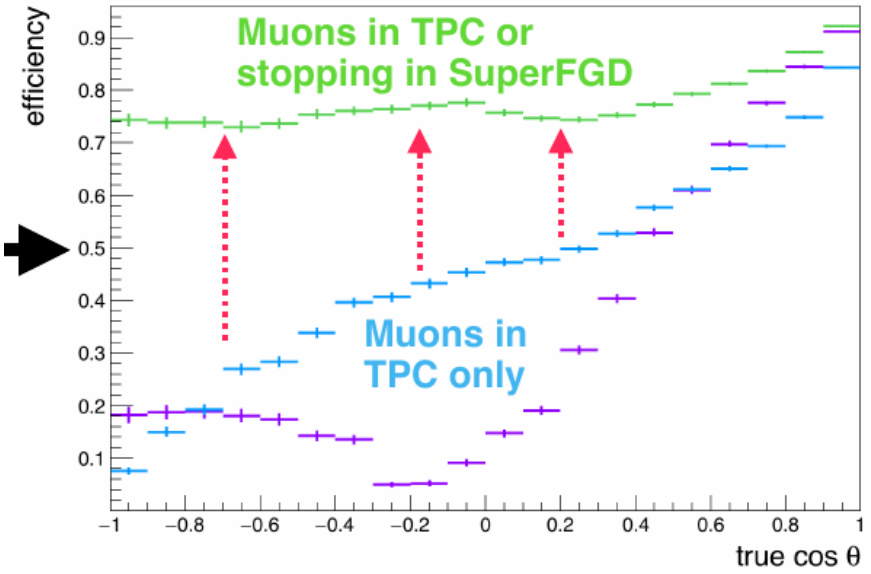
Future Propects





Upgrade of the Near Detector ND280

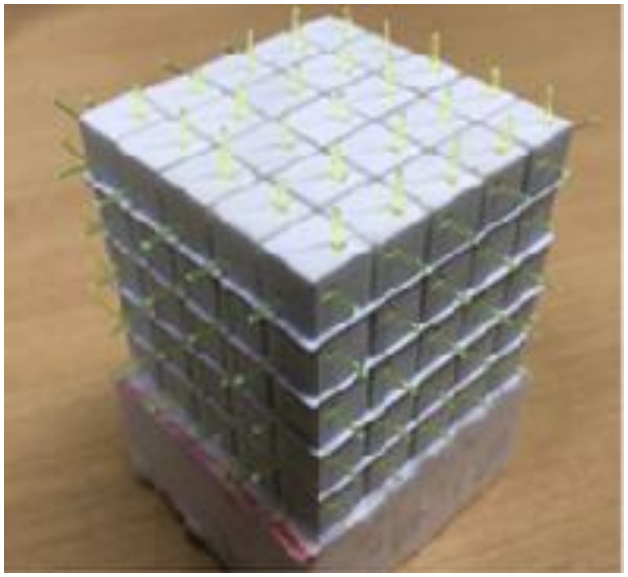


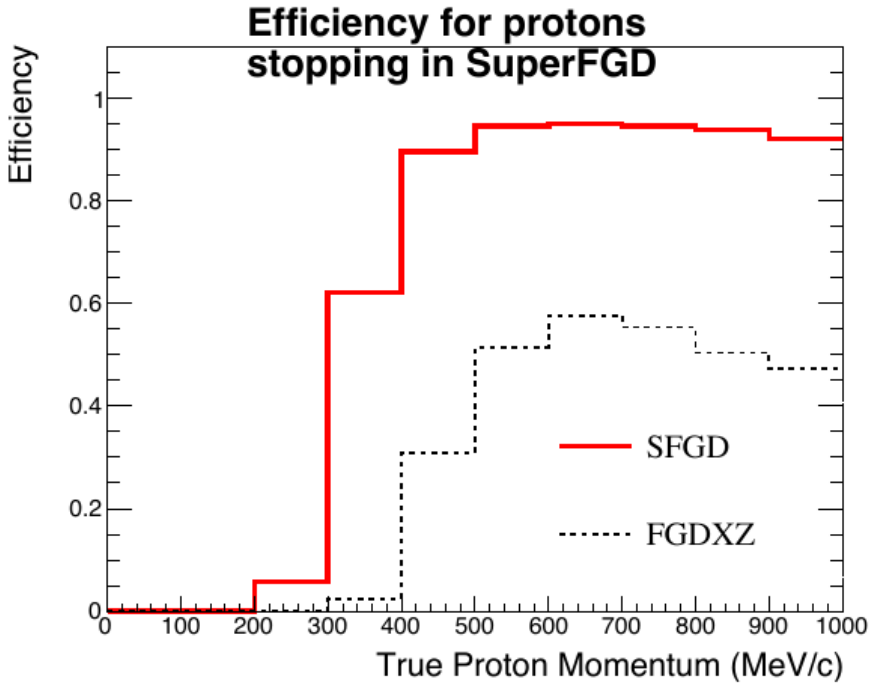


High Angle TPCs:

- Improved acceptance at large scattering angles
- Measure phase space not accessible up to now
- Improved cross-section measurements

Upgrade of the Near Detector ND280

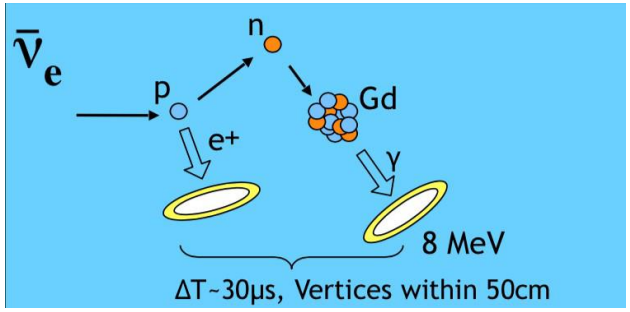




Super FGD:

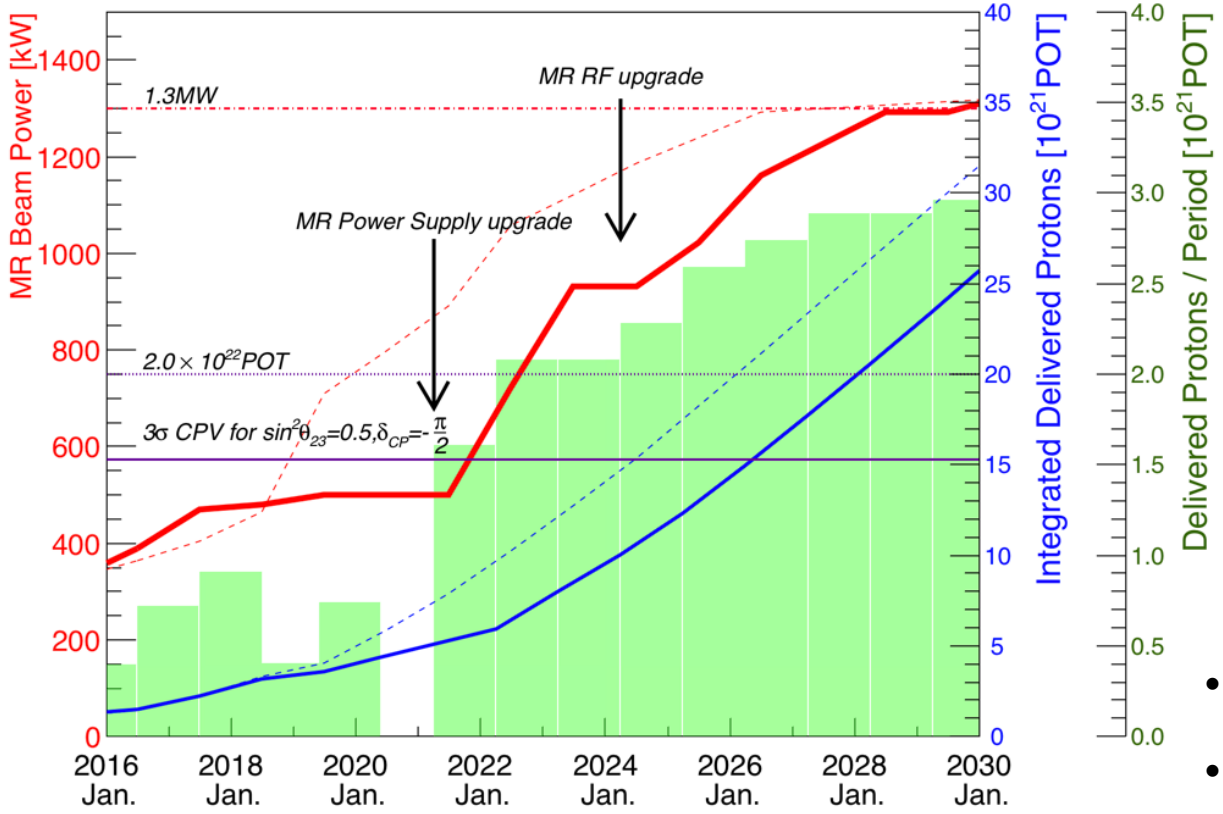
- 1 cm^3 scintillator cubes with fibre readout
- Quasi-3D imaging
- Improved proton detection threshold and neutron detection capabilities
- More complete reconstruction of final states

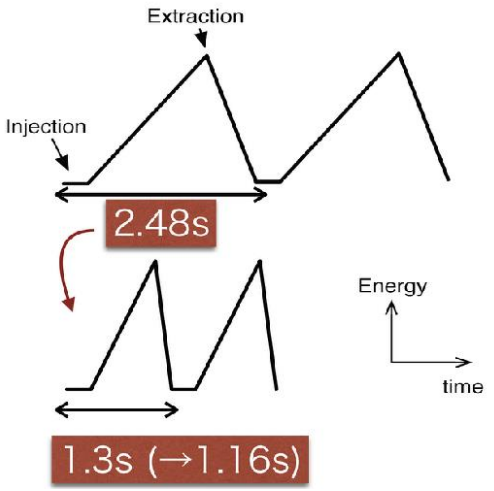
Gadolinium Loading of Super-K



- enhanced neutron detection improves $\bar{\nu}_e$ detection
- provides wrong-sign background constraint in $\bar{\nu}_e$
- Load with $Gd_2(SO_4)_3$ up to 0.2%

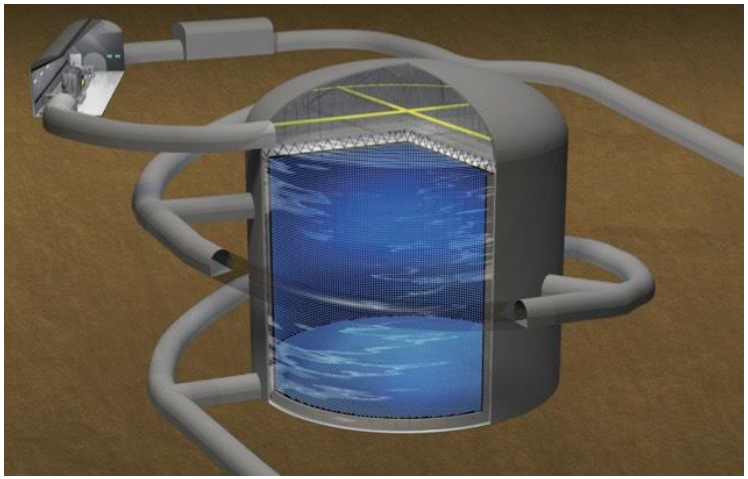
Beam Upgrade



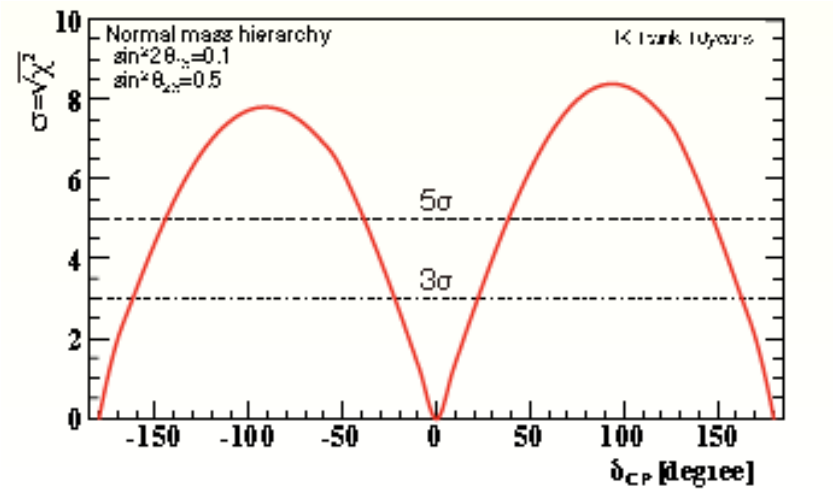


- 2019: beam at **515 kW**
- 2023: expect **800 kW**
- Ultimate goal: **1300 kW**

Hyper Kamiokande



	Super-K	Hyper-K
Site depth	Mozumi 1000m	Tochibora 650m
Number of photomultipliers	11,129	40,000
Photomultiplier coverage	40%	40% (2 x QE)
Mass Fiducial mass	50 kt 22.5 kt	260 kt 188 kt



- Up to 2000 $\nu_e/\bar{\nu}_e$ events (115 in T2K)
- Same off-axis angle as T2K
- Same near detector
- 5 σ discovery of CP violation

Thank You