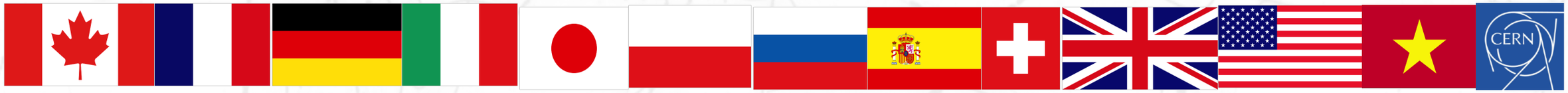
UNIVERSITÉ DE GENÈVE
FACULTÉ DES SCIENCES

T2K experiment

Federico Sánchez for the T2K collaboration
Université de Genève

T2K collaboration

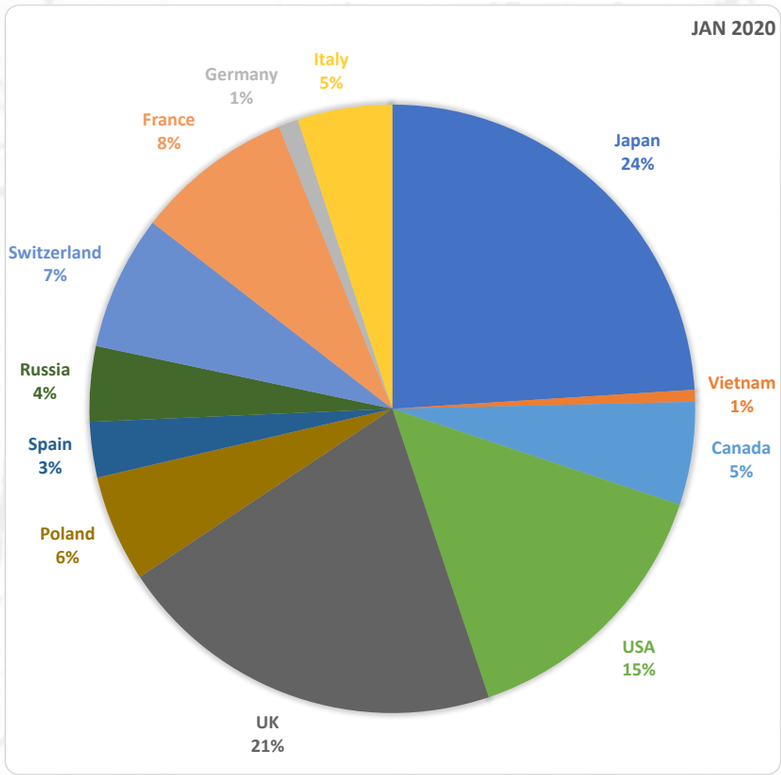


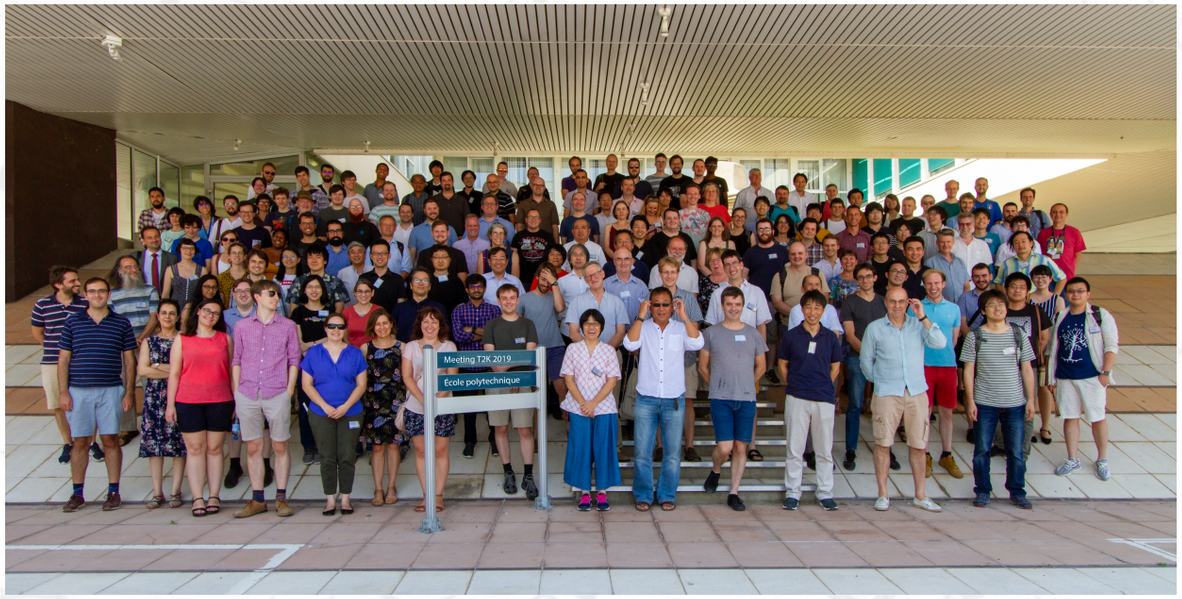
~500 members, 69 institutes, 12 countries

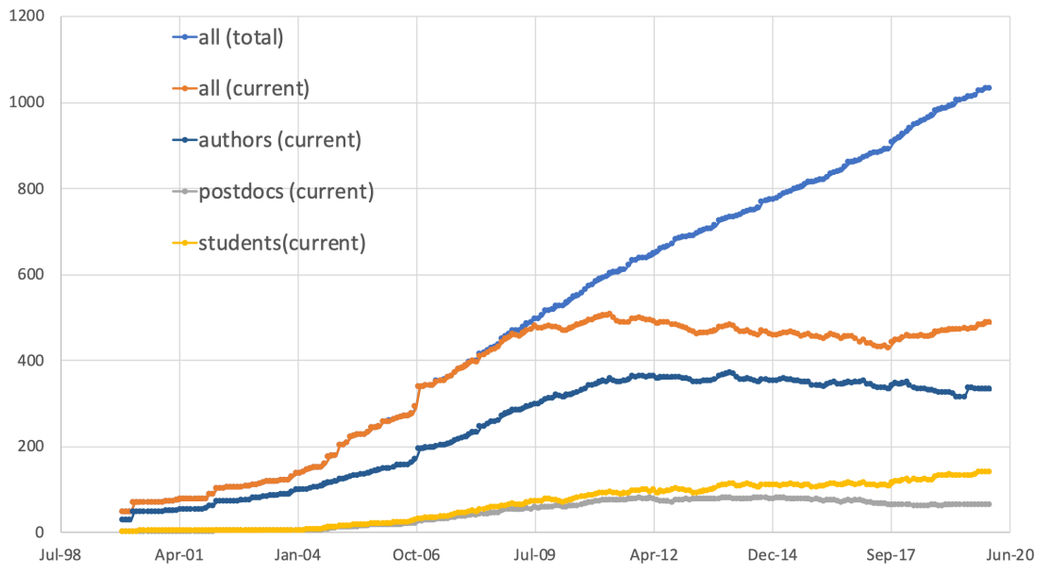
Asia	117
Japan	114
Vietnam	3

Americas	96
Canada	26
USA	70

Europe	262
France	40
Germany	5
Italy	24
Poland	27
Russia	19
Spain	14
Switzerland	34
UK	99

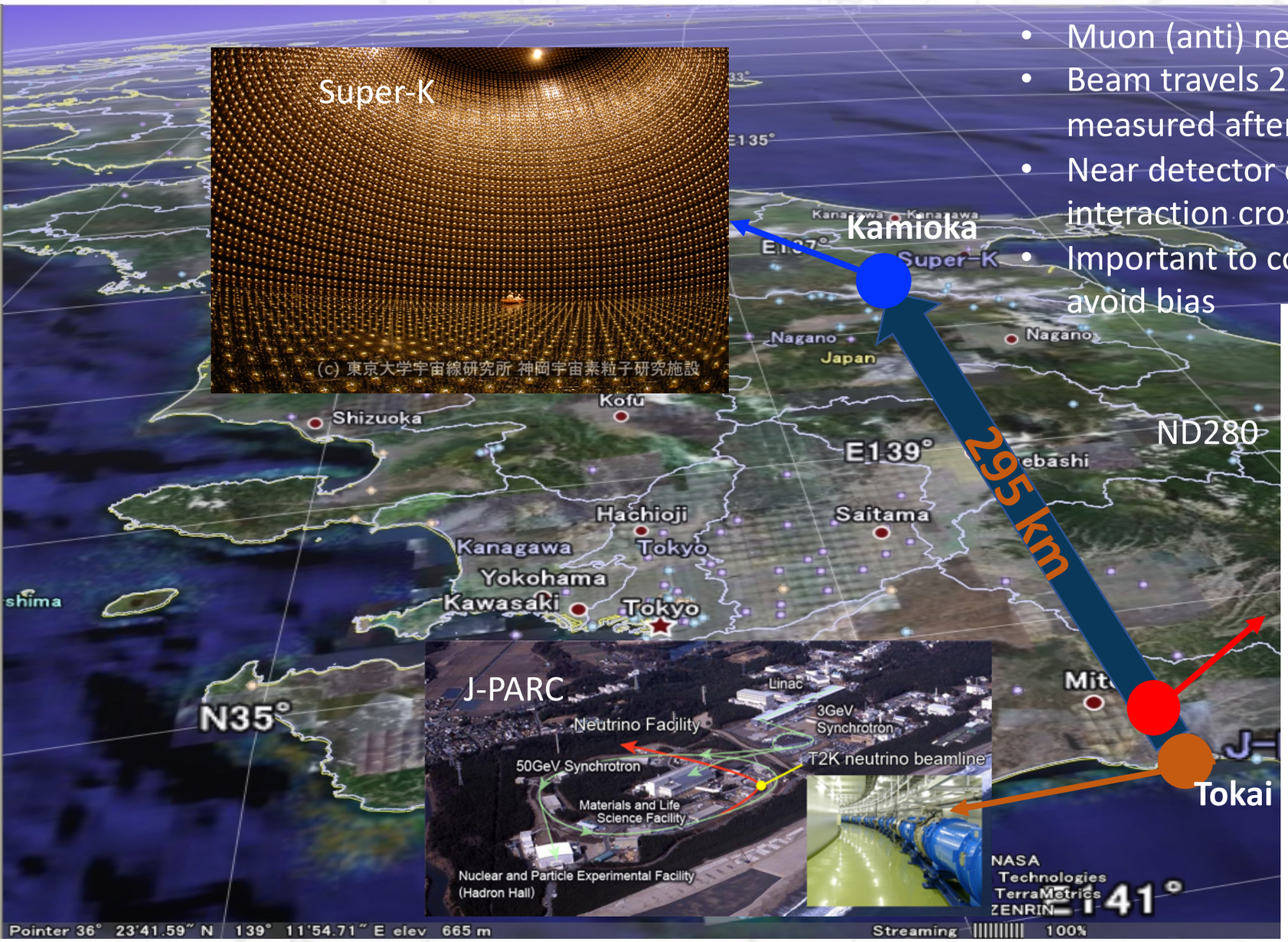


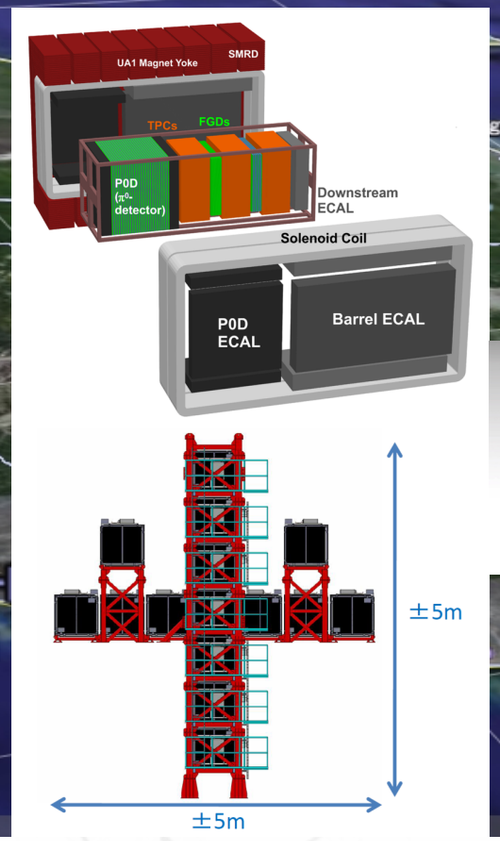




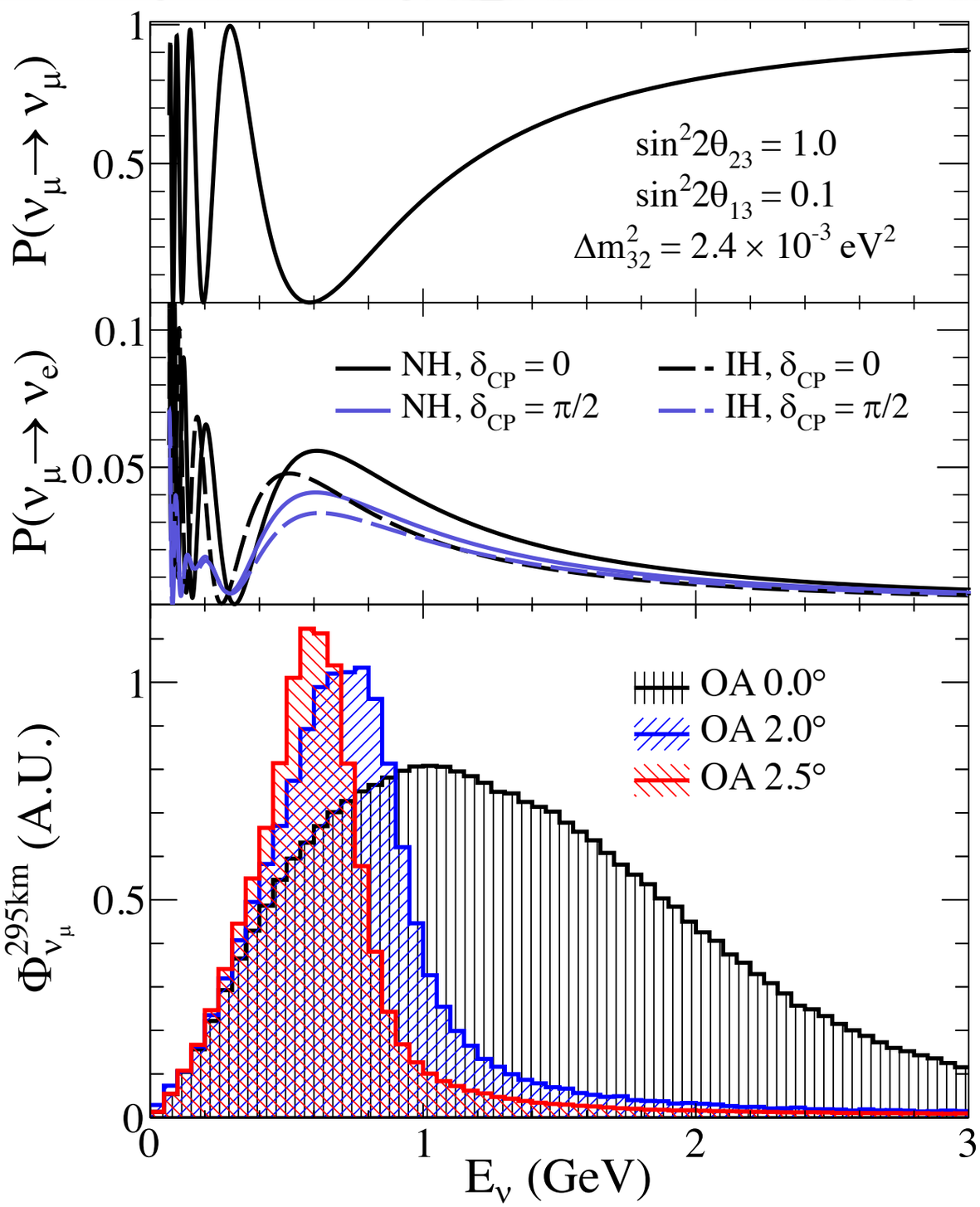
T2K experiment

- Muon (anti) neutrino beam generated at J-PARC
- Beam travels 295 km to large SK far detector to be measured after oscillations
- Near detector complex, ND280 constrains beam flux and interaction cross-section before oscillation
- Important to constrain non-oscillation parts of model to avoid bias





Neutrino oscillations in T2K



Muon (anti)neutrino disappearance

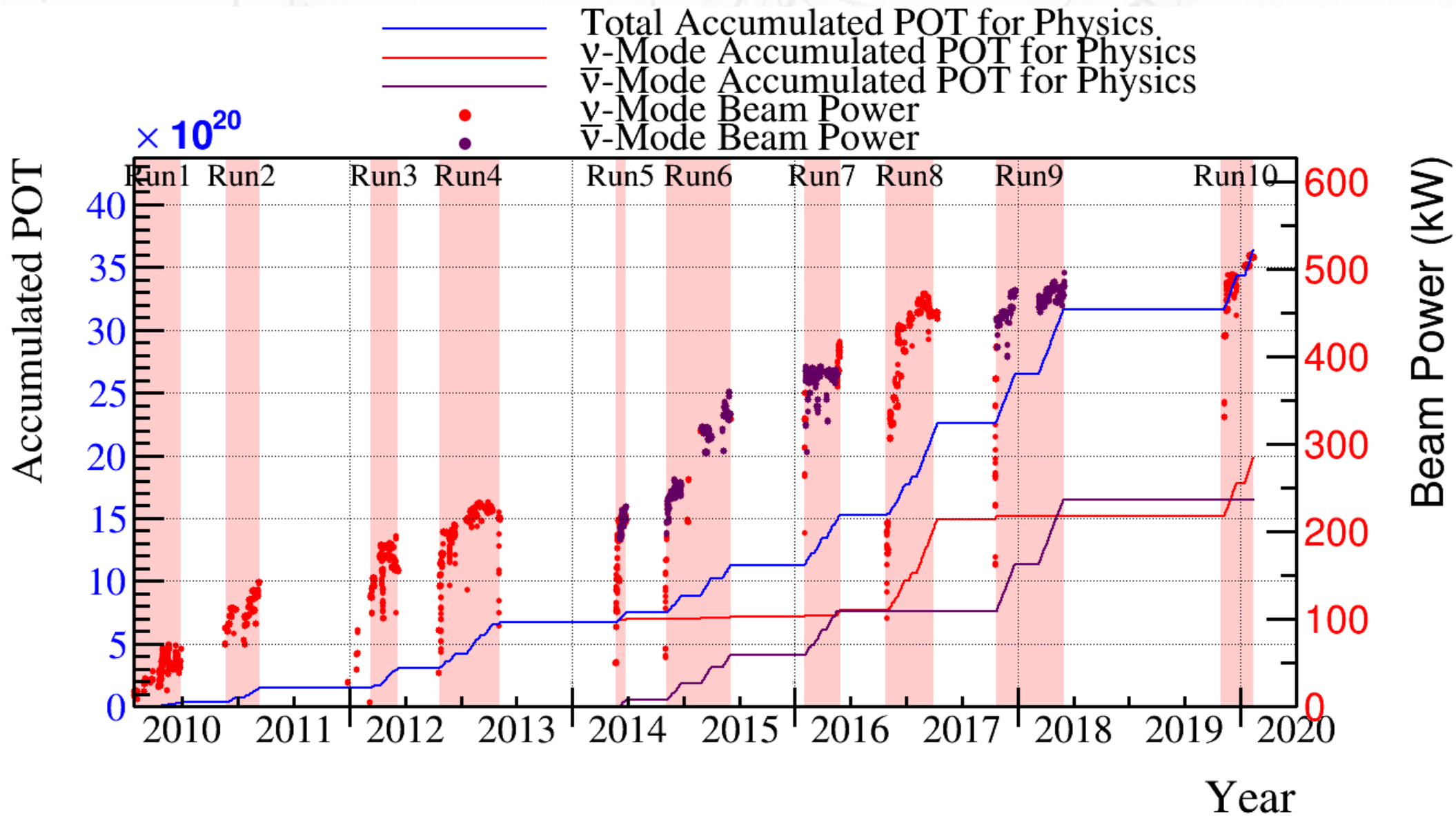
- Location of dip determined by Δm^2_{32}
- Depth of dip determined by $\sin^2(2\theta_{23})$

Electron (anti)neutrino appearance

- Leading term depends on $\sin^2(\theta_{23})$, $\sin^2(\theta_{13})$ and Δm^2_{32}
- Sub-leading δ_{CP} dependance (up to 45% on event rate)
  - $\delta_{CP} = \pi/2$: fewer neutrinos, more anti-neutrinos
  - $\delta_{CP} = -\pi/2$: more neutrinos, fewer anti-neutrinos
- Matter effects give dependence on mass hierarchy (~10%)

- For 295km baseline first oscillation maximum is at 0.6 GeV: T2K uses 2.5° off axis beam to focus flux at this energy

Accumulated beam

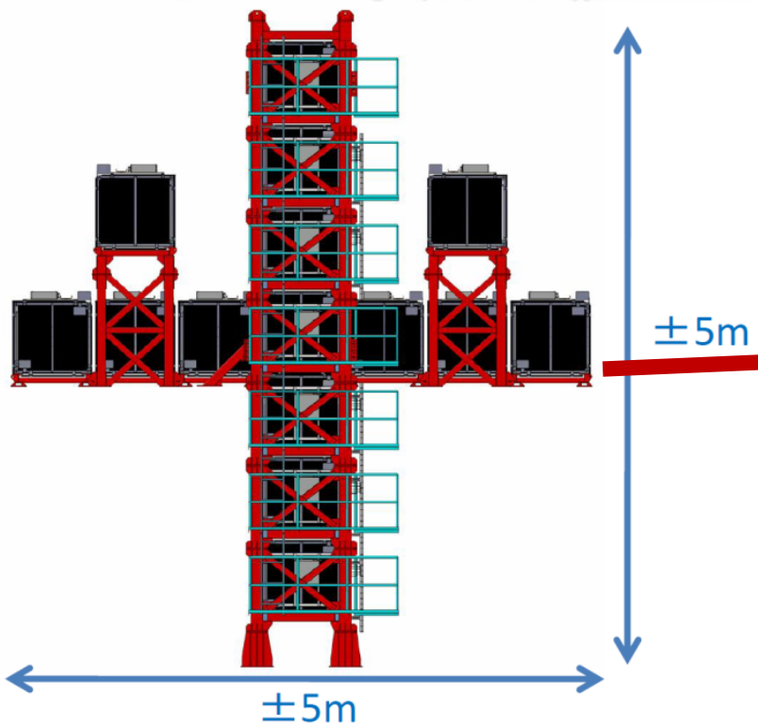


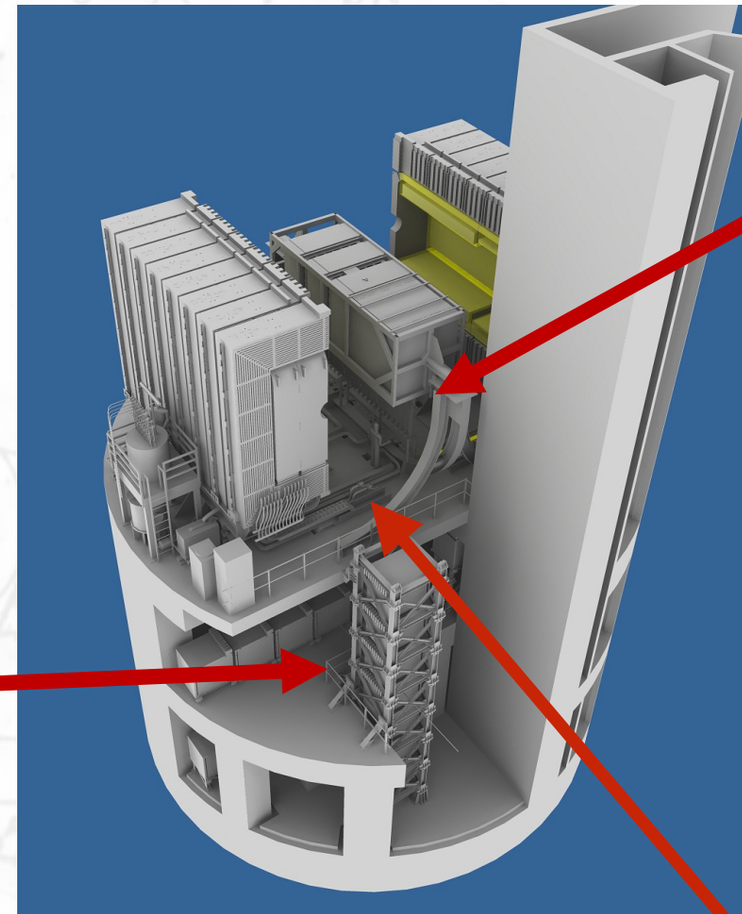
- 515 kW stable operation achieved in 2020.
- 33% more ν's since 2018.
- Total of 1.97×10^{21} POT in ν-mode and 1.63×10^{21} in $\bar{\nu}$-mode.

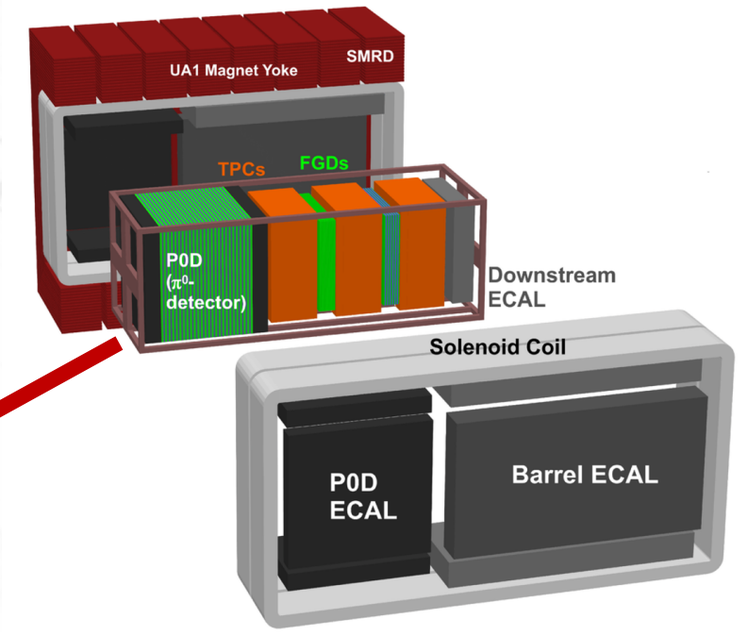
T2K Near detector's

INGRID

- On-axis detector
- Monitors beam direction and monitors stability







ND280

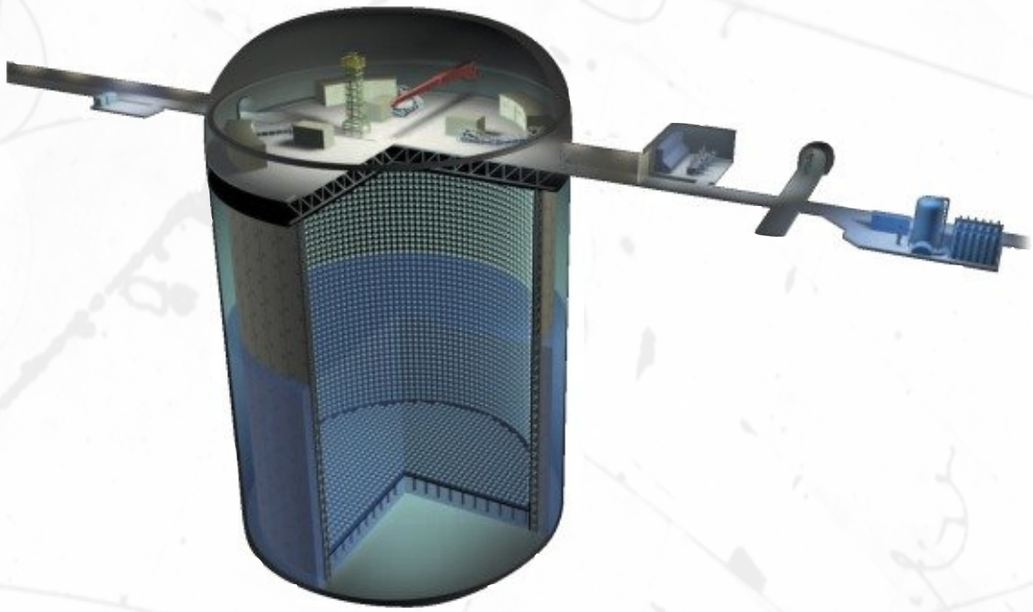
- Water and CH targets with magnetized tracker to measure momentum and charge
- 2.5° off-axis (same as Super-K)
- Constrains cross-section and flux uncertainty model

Wagasci/BabyMind

- Water and CH targets with magnetized muon catcher to measure μ momentum and charge
- 2.5° off-axis
  - Intermediate off-axis for flux measurements.

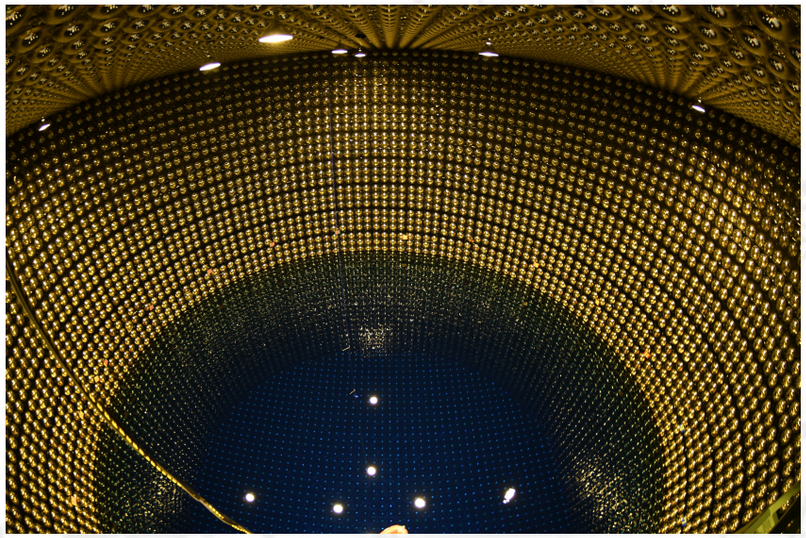
T2K far detector: SuperKamiokande

50 kt water-Cherenkov detector



11,000 20” PMT inner detector

40% photo-coverage



2,000 8” PMT outer detector

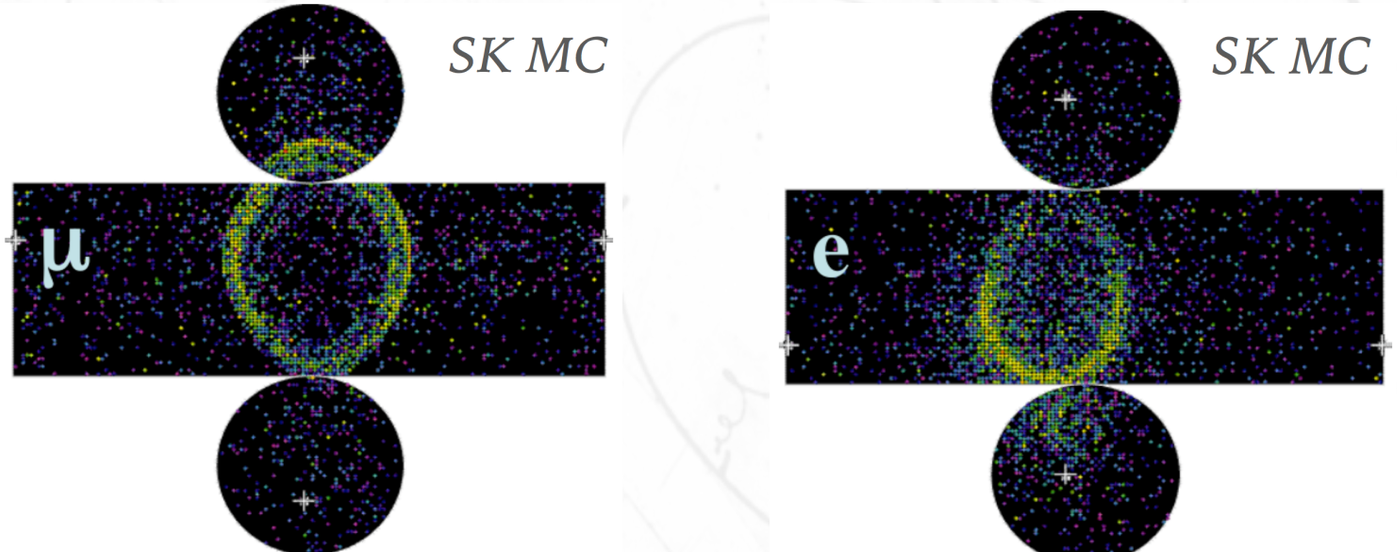
Cosmic veto/exiting particles

Particle ID via Cherenkov ring pattern:

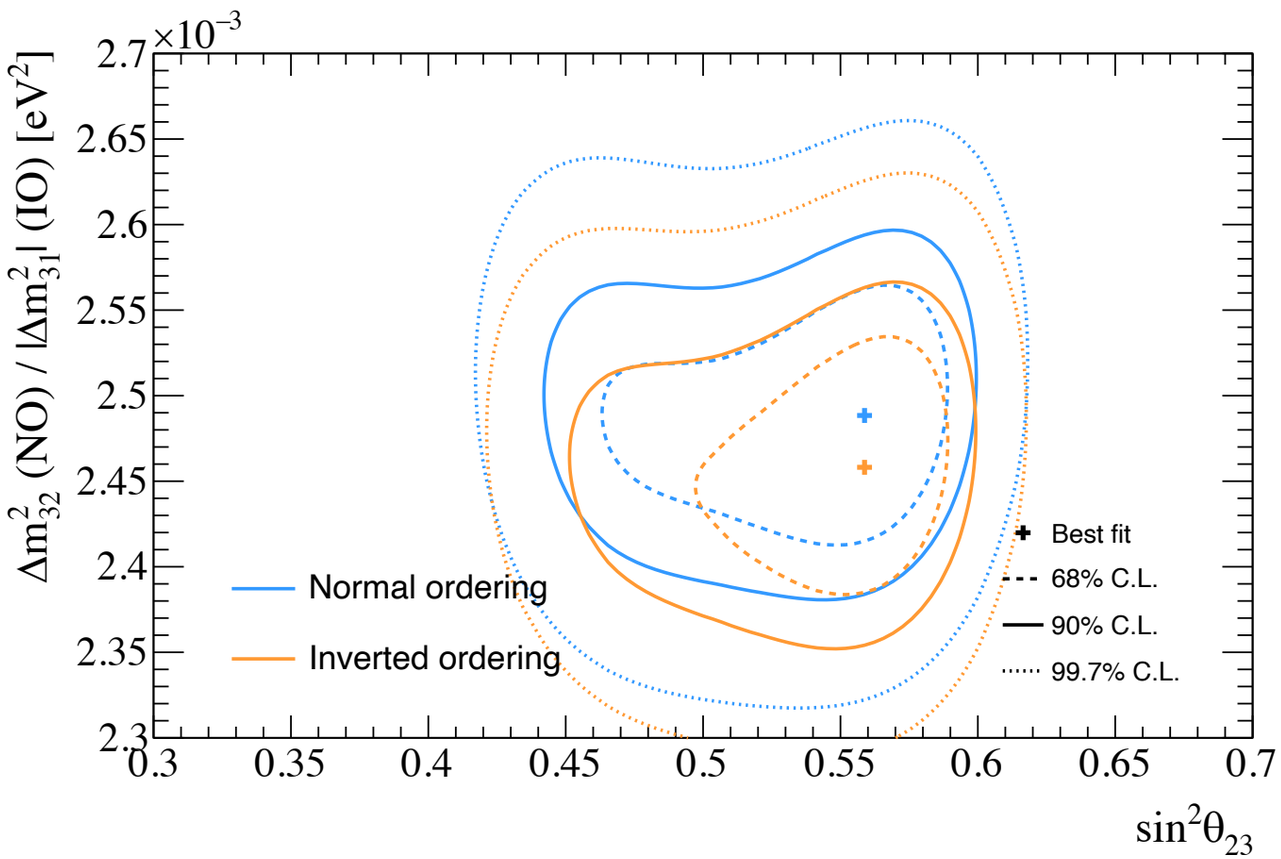
Muons → sharp rings

Electrons scatter more → fuzzier rings

No charge identification



Atmospheric sector



Posterior probability

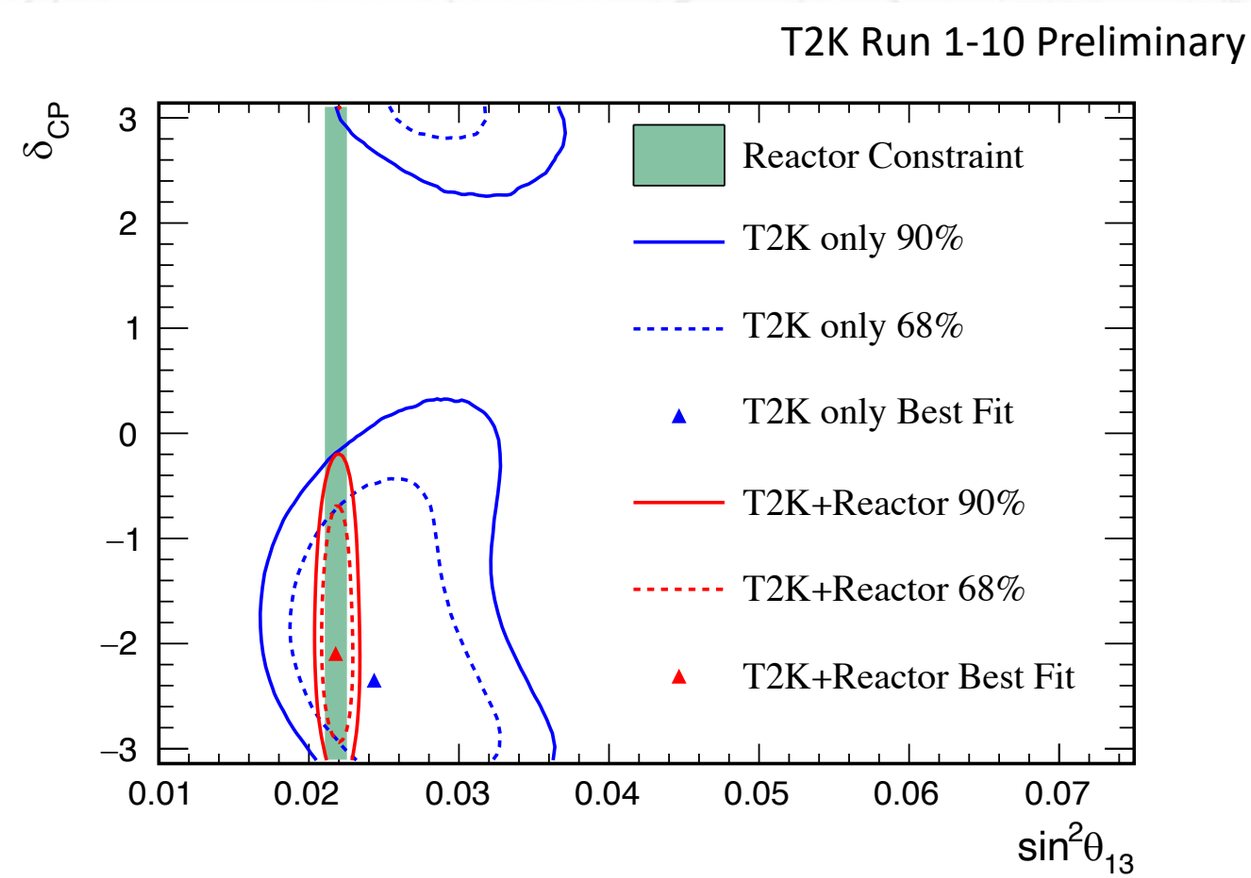
	$\sin^2\theta_{23} < 0.5$	$\sin^2\theta_{23} > 0.5$	Sum
NH ($\Delta m^2_{32} > 0$)	0.195	0.613	0.808
IH ($\Delta m^2_{32} < 0$)	0.034	0.158	0.192
Sum	0.229	0.771	1.000

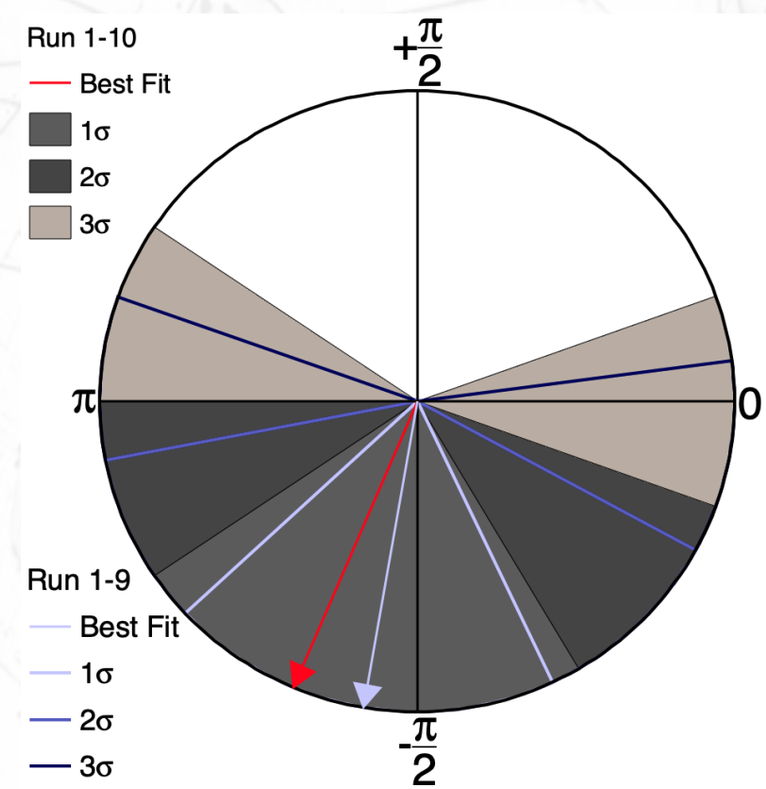
- Data shows preference for normal hierarchy and upper octant
- Slight preference for non-maximal $\sin^2\theta_{23}$

.

θ_{13} and δ_{CP}

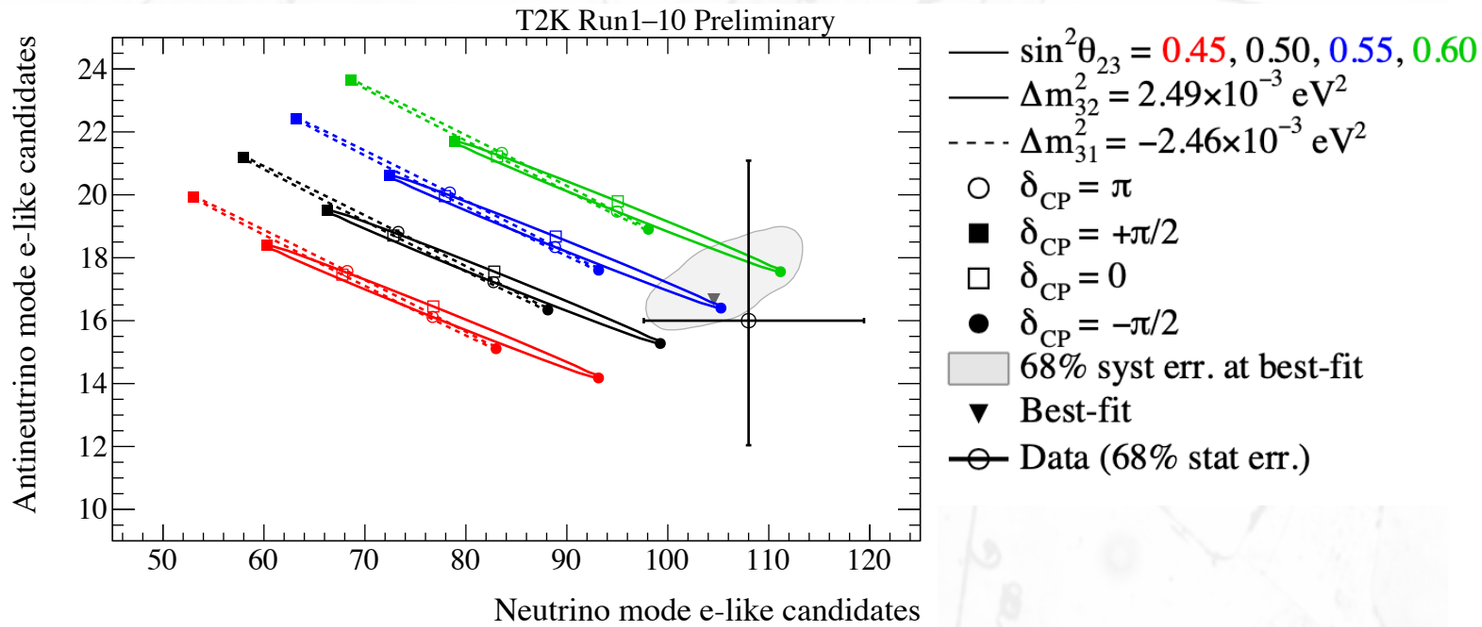
- T2K data alone and using PDG2019 constraint on θ_{13} from reactor experiments
- T2K only intervals are compatible with PDG2019 θ_{13} values at better than 1σ
- Results from here on are with reactor constraint

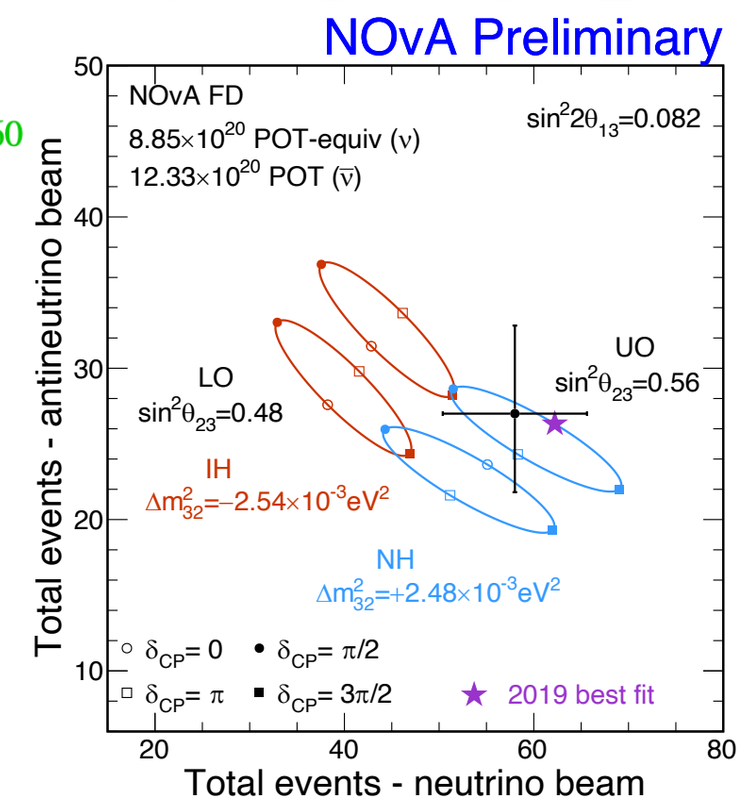




T2K/Nova Joined fits

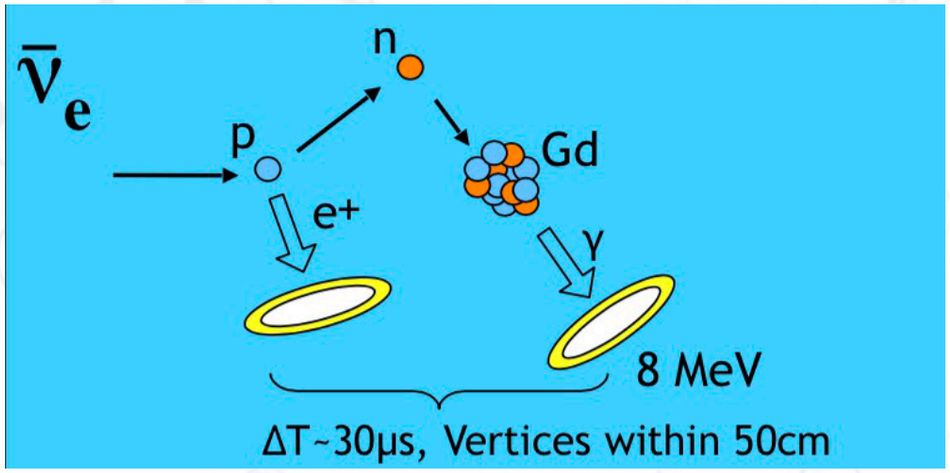
- Experiments with different neutrino energies have different oscillation probabilities and systematic uncertainties
- Combined analysis of data allows degeneracies to be broken and maximises impact of data taken



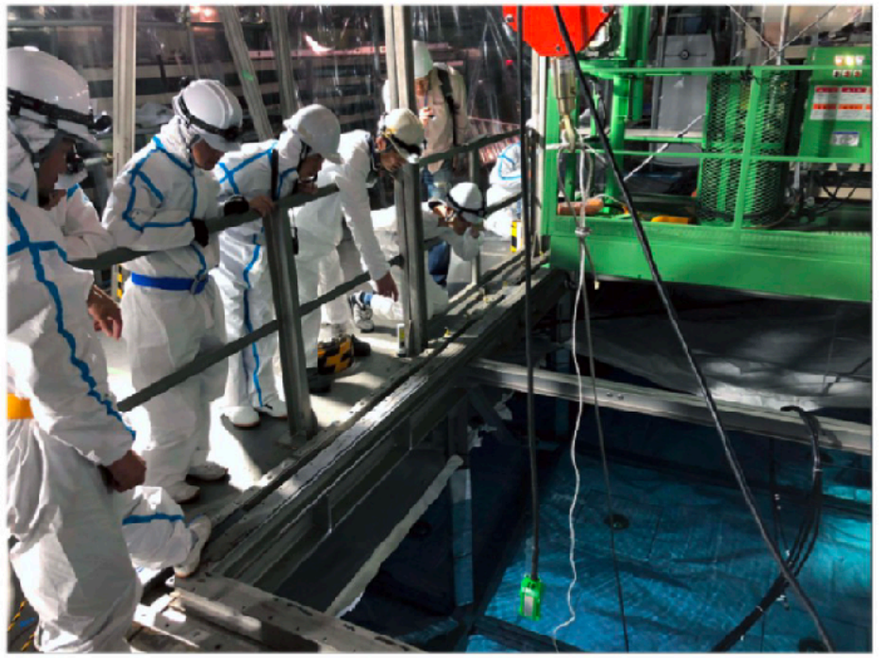


Separated LoI submitted to Snowmass.

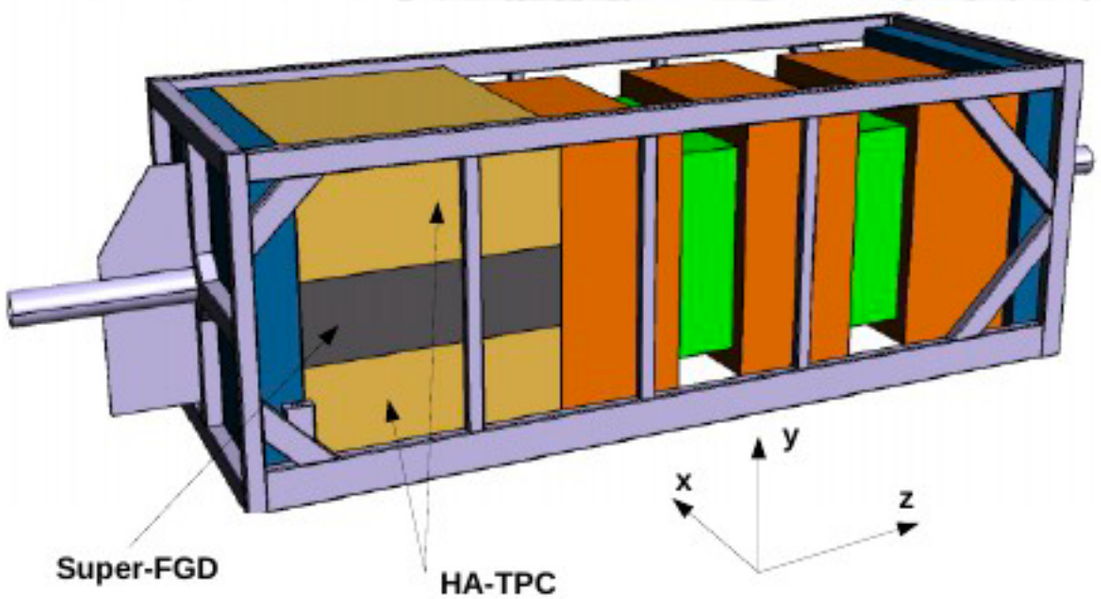
SK Gadolinium

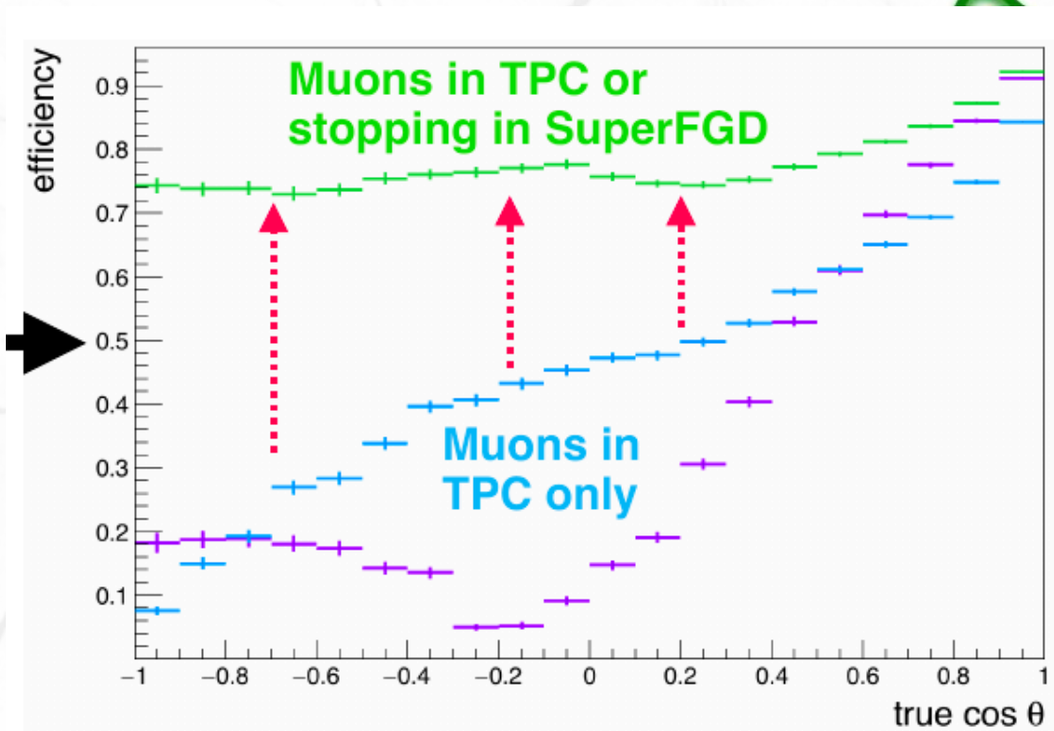


- SK Gadolinium project
  - enhance neutron detection improve low-energy ν_e detection (non-T2K goal).
  - may provide wrong-sign background constraint in $\bar{\nu}_e$
    - more data samples.
- Leak repairs to SK tank finished in 2019.
- Load $Gd_2(SO_4)_3$ in stages up to 0.2%.
- Loading started!!!!!

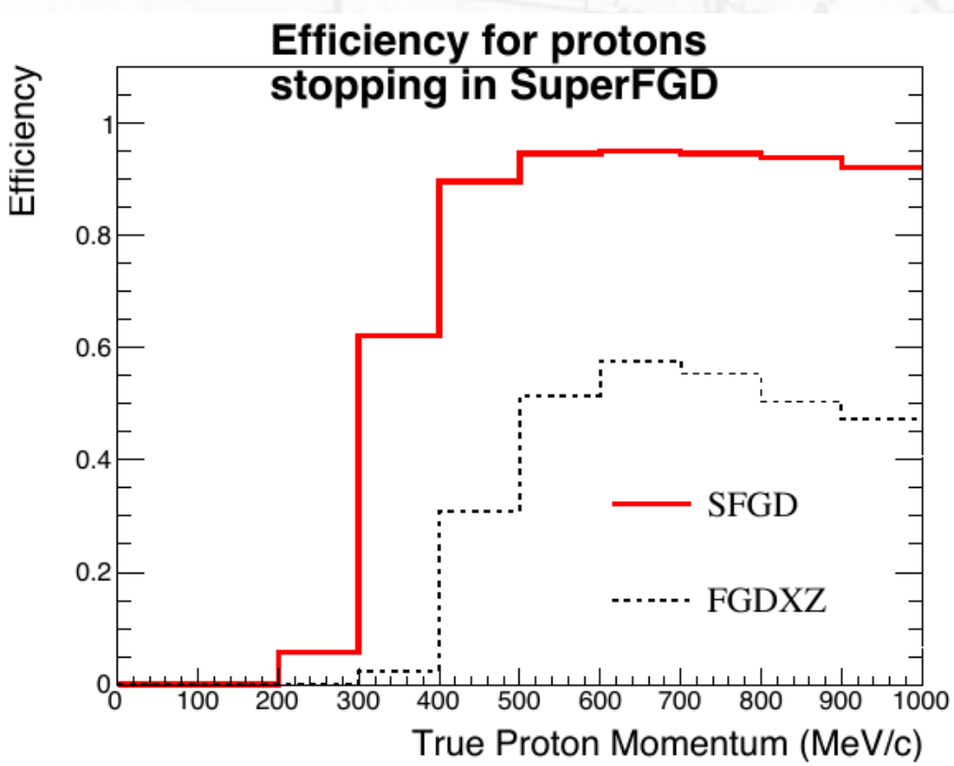


ND280 upgrade





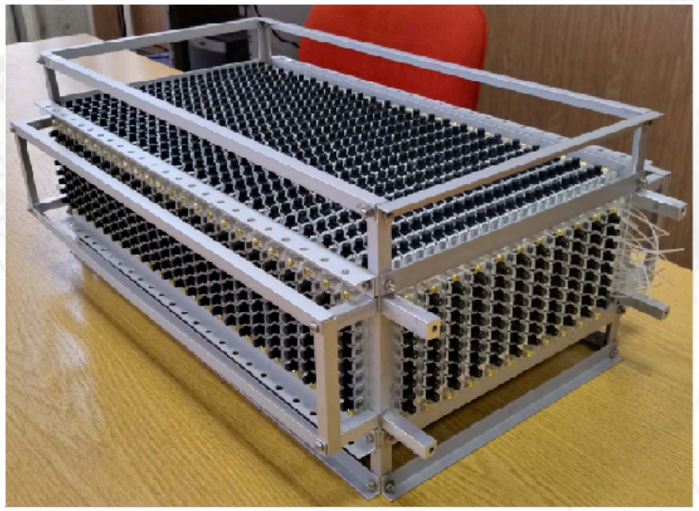
ND280 upgrade detector is the response to a decade of operation experience.



ND280 upgrade goals

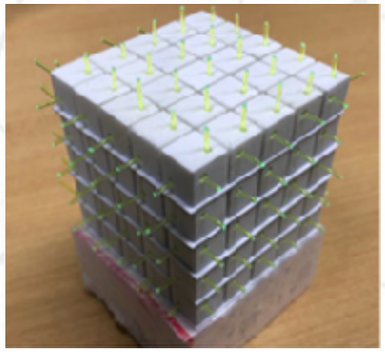
- Keep old ND280 performance with:
  - higher granularity: reduce tracking thresholds.
  - high angle tracks: backward going tracks.
  - time of flight for track direction determination.

sFGD

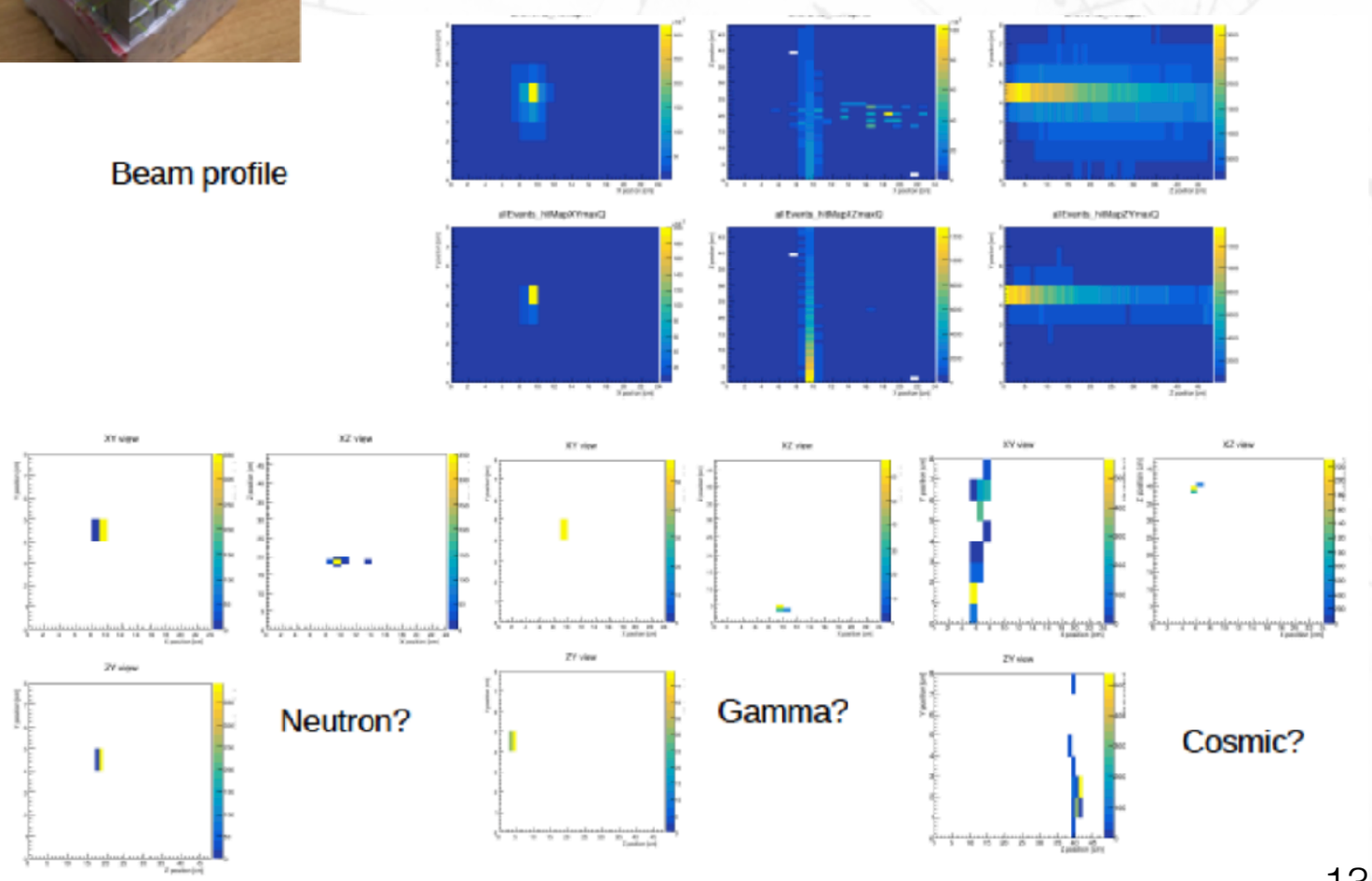


- 2,000,000 cubes
- 2 tons
- 65,000 readout channels.
- quasi-3D geometry.
  - short proton range.
  - 4π uniformity.
- ~60% neutron-detection efficiency.
- 950 ps time resolution.

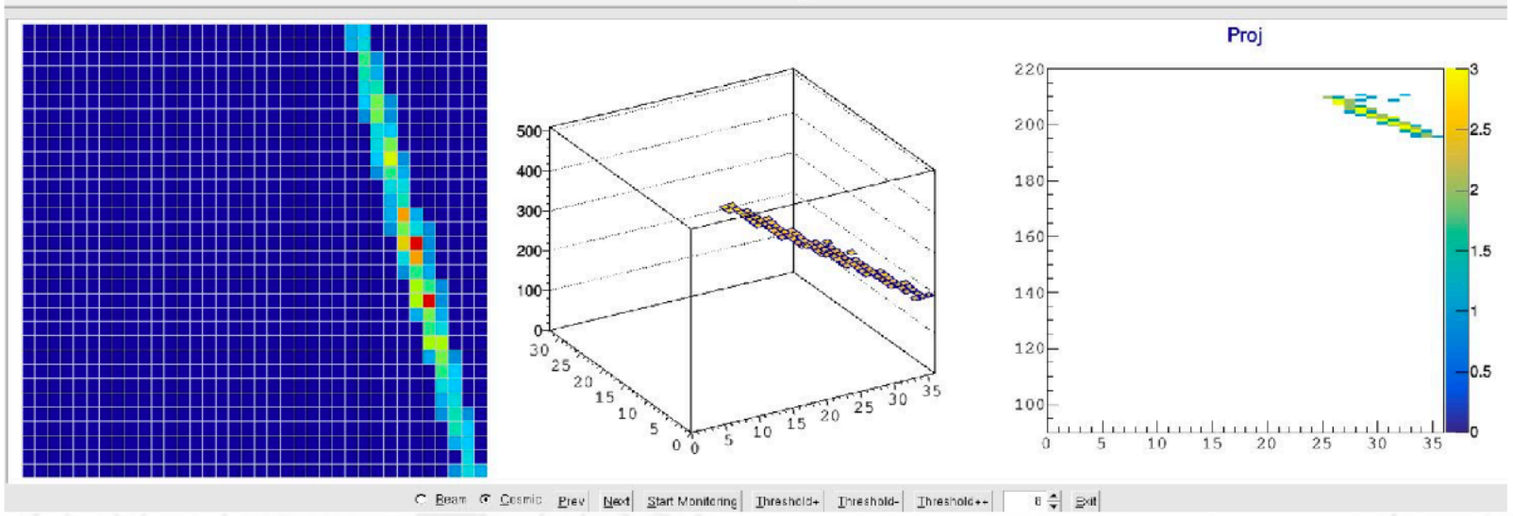
Improve physics related to hadron detection in neutrino scattering.



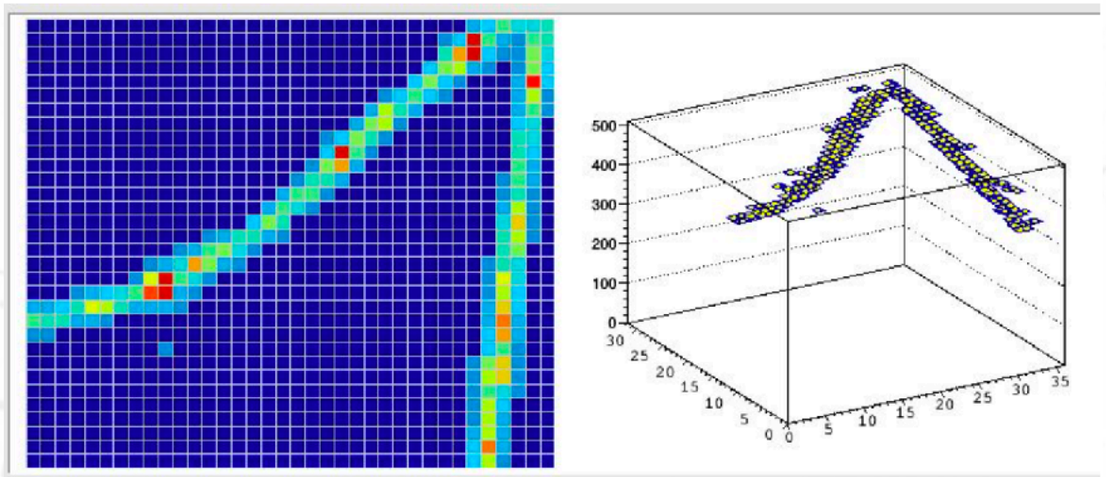
Neutron beam @ LANL

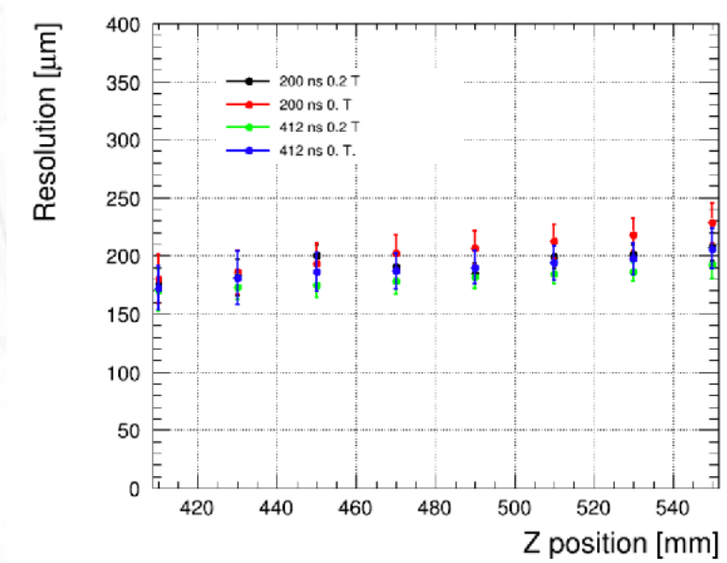


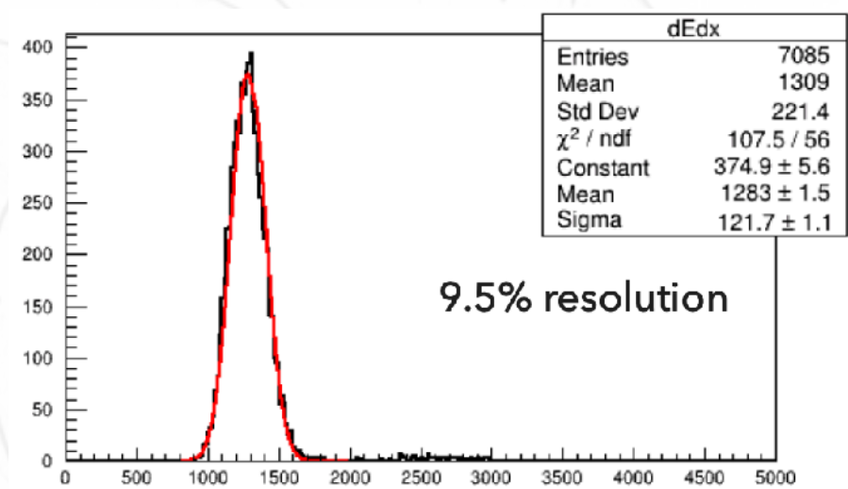
HA-TPC



- high angle track detection.
- resistive plate MM for better point resolution.
- Very thin field-cage to increase detector acceptance for low momentum particles.

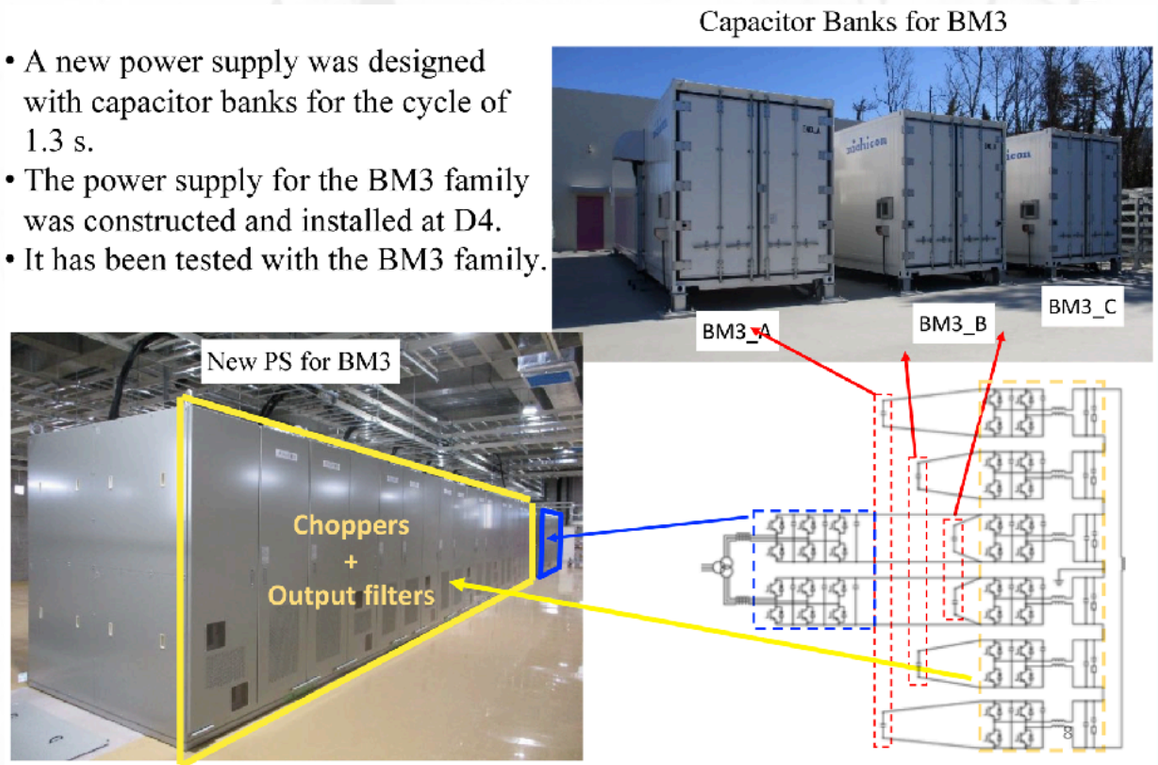


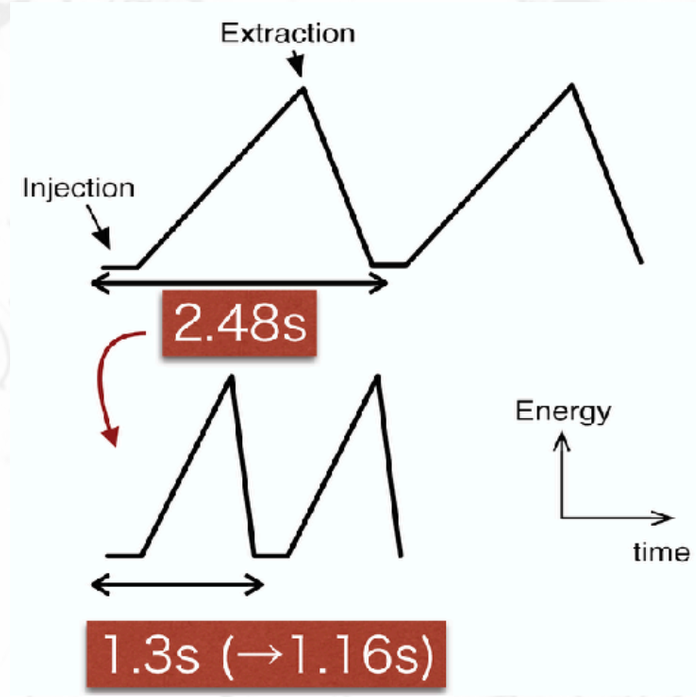




Beam upgrade

- A new power supply was designed with capacitor banks for the cycle of 1.3 s.
- The power supply for the BM3 family was constructed and installed at D4.
- It has been tested with the BM3 family.





f_{rep}=0.4 Hz ⊕ PPP = 2.7×10^{14} ⊕ 30 GeV = 515 kW

515 kW stable operation in 2019/20

MR Power Supply approved

JFY 2020

f_{rep}=0.77 Hz ⊕ PPP = 2.2×10^{14} ⊕ 30 GeV = 810 kW

exp. >800 kW by 2023

RF upgrade and Machine development

f_{rep}=0.86 Hz ⊕ PPP = 3.2×10^{14} ⊕ 30 GeV = 1.3 MW

exp. >1 MW by 2027

KEK's plan for future neutrino experiments at J-PARC

July 6, 2020

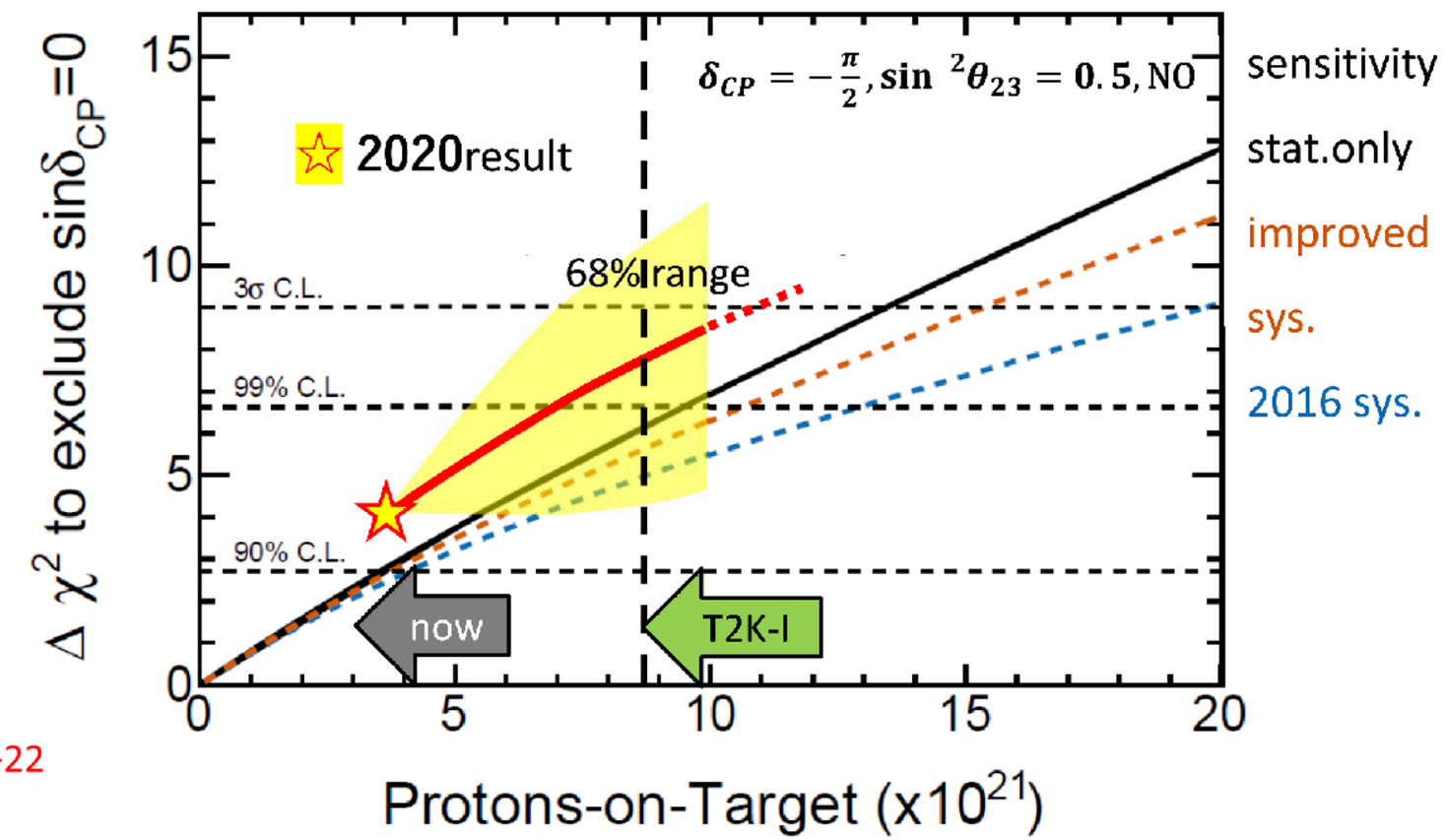
- The Hyper-Kamiokande (HK) project has been approved by the Japanese government and has officially started. It aims to begin operations in 2027. KEK will realize the upgrade of J-PARC for the HK project.

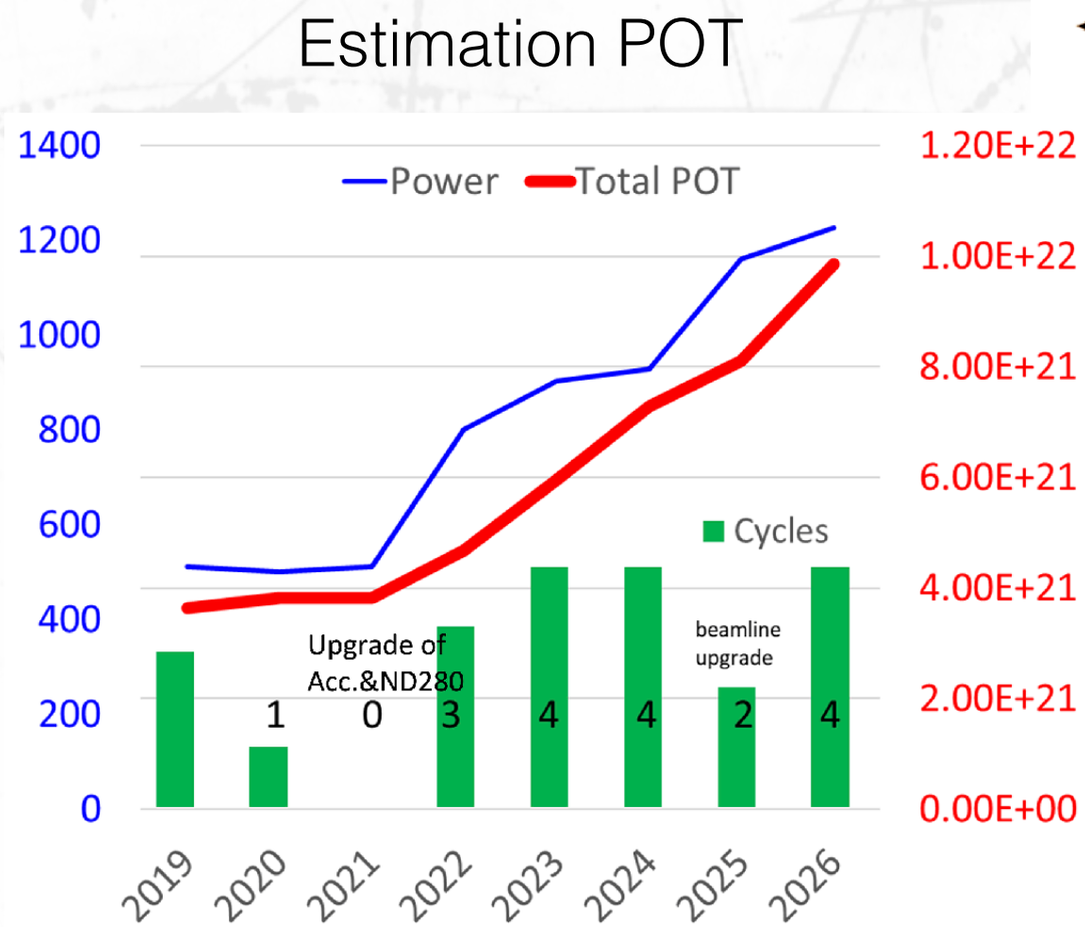
- KEK acknowledges the consensus of the community involved in the Japan-based neutrino experiments that states the need for T2K beam operations until at least 10×10^{21} POT in total.

- KEK recognizes the importance of T2K operation with the upgraded near detector (ND280) for further advancement of CPV measurements. This will also strengthen international collaboration on T2K and HK, contribute to the success of the neutrino program in Japan, and enhance the physics program of HK with an upgraded beam intensity from the start of its operation.

- In light of the above, KEK will make its best effort to provide approximately four months of T2K beam operations per year until the start of HK.

Prospects





To be further improved by ND280 upgrade etc.
If CP is maximally violated, we have a good chance to reach 3σ.

Summary

- Exciting new results from T2K: Indication of maximally violated parity.
- Upgrades:
  - Beam upgrade to reach 1 MW by 2027.
  - ND upgrade to improve on model constrains.
  - SuperKamiokande Gadollinium run.
- KEK supports the running of T2K until HyperKamiokande.
- There is a chance T2K can exclude no CP violation phase with 3 sigma significant.

The international journal of science / 16 April 2020
nature
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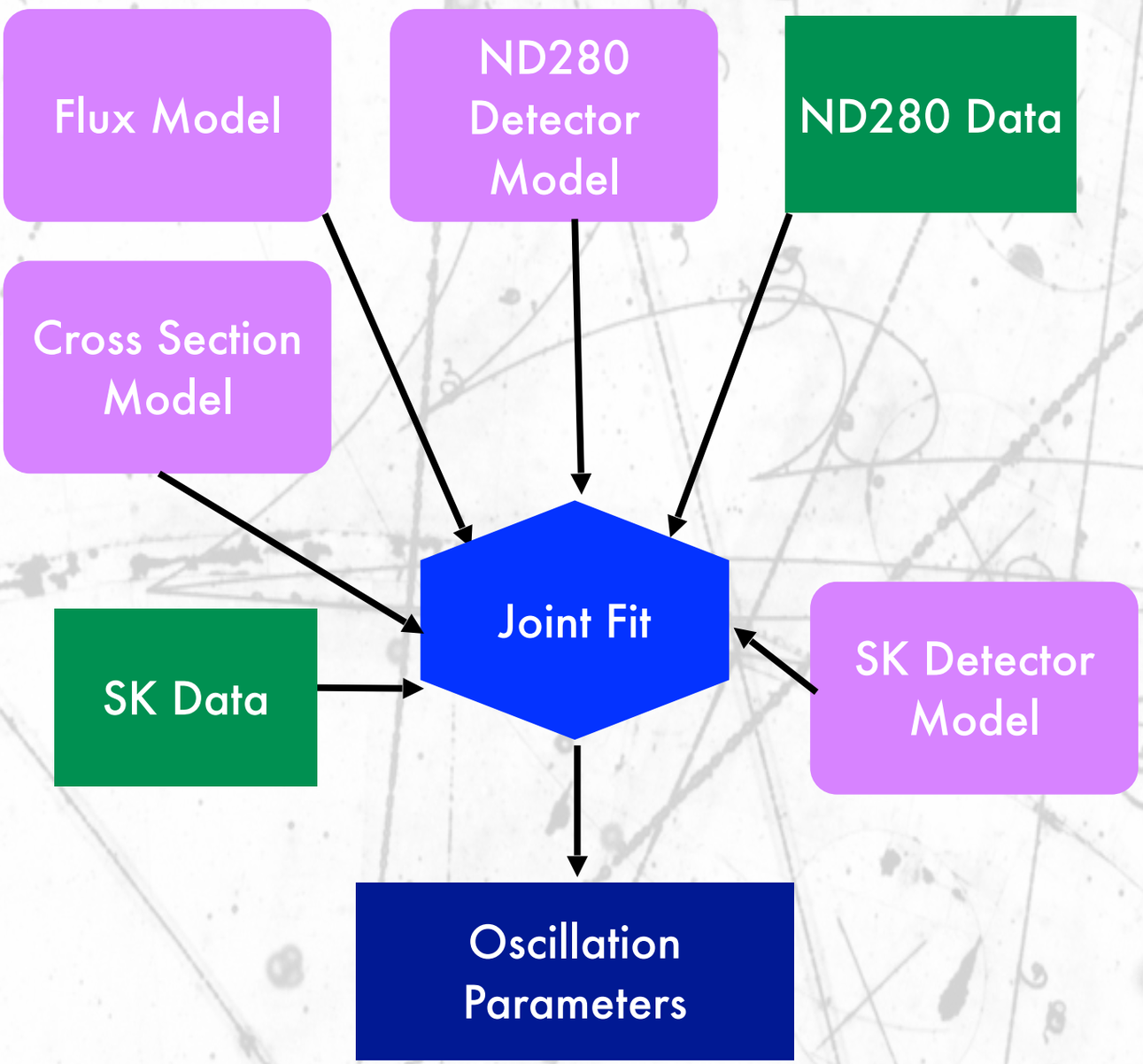
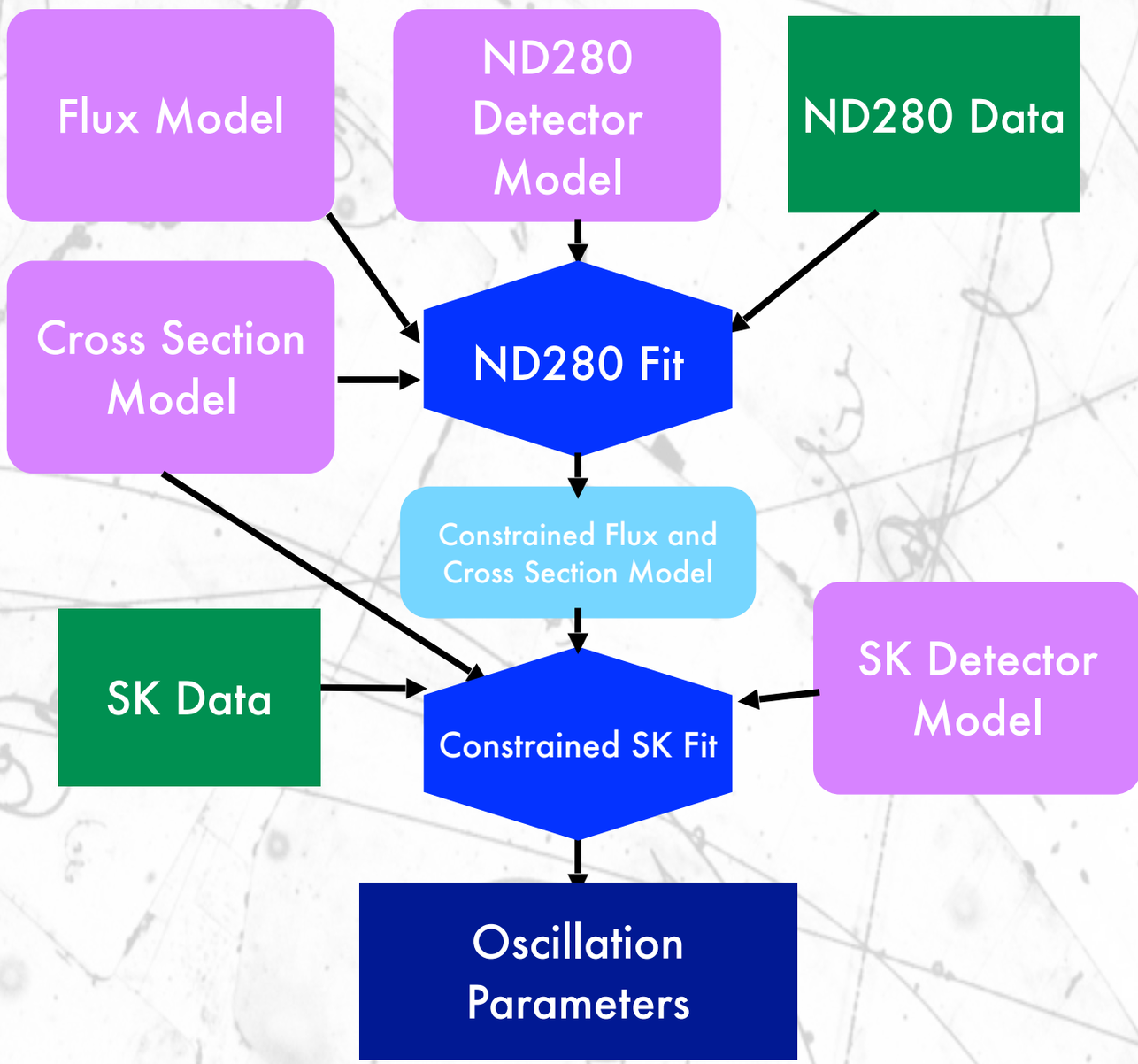
Support slides

Statistical methods



Joint Fit



Separate ND and SK Fits