Introduction: T2K

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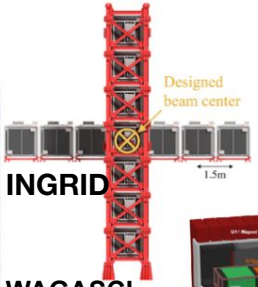
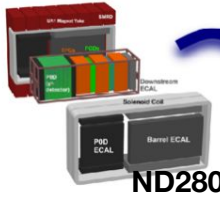
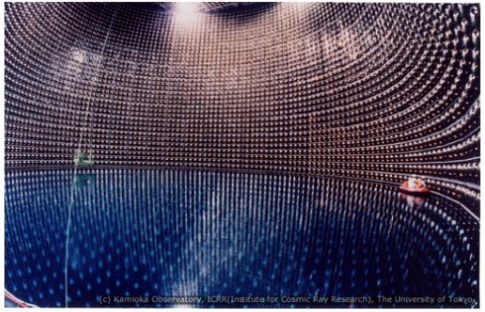
on behalf of the T2K experiment

The T2K experiment



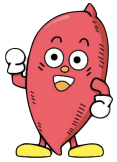


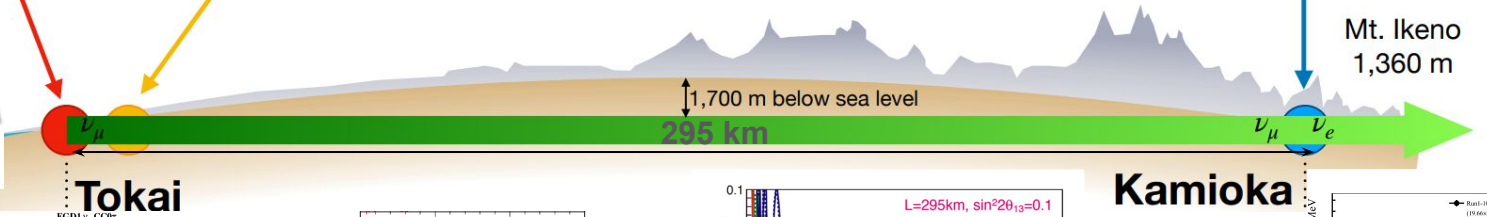


J-PARC

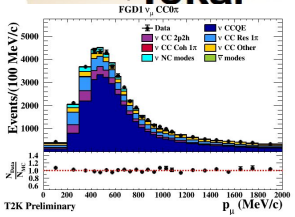
Near Detectors

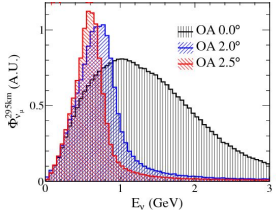
Super-Kamiokande



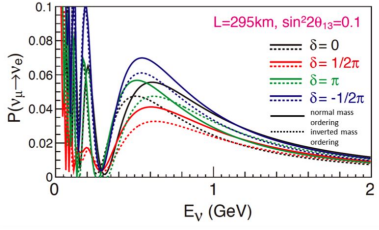


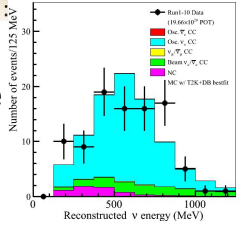
ν_μ beam



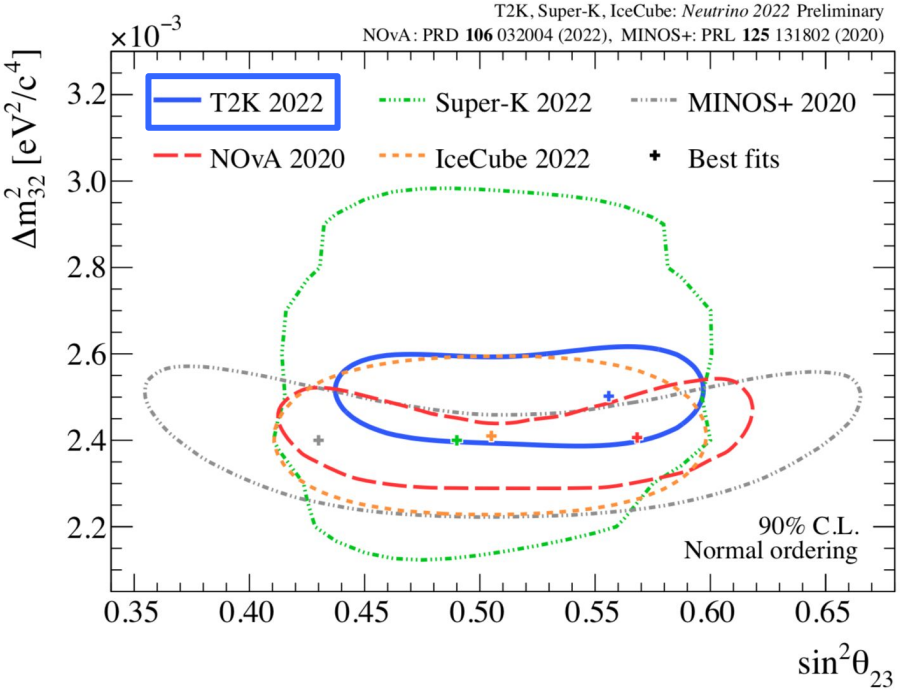


ν_e appearence



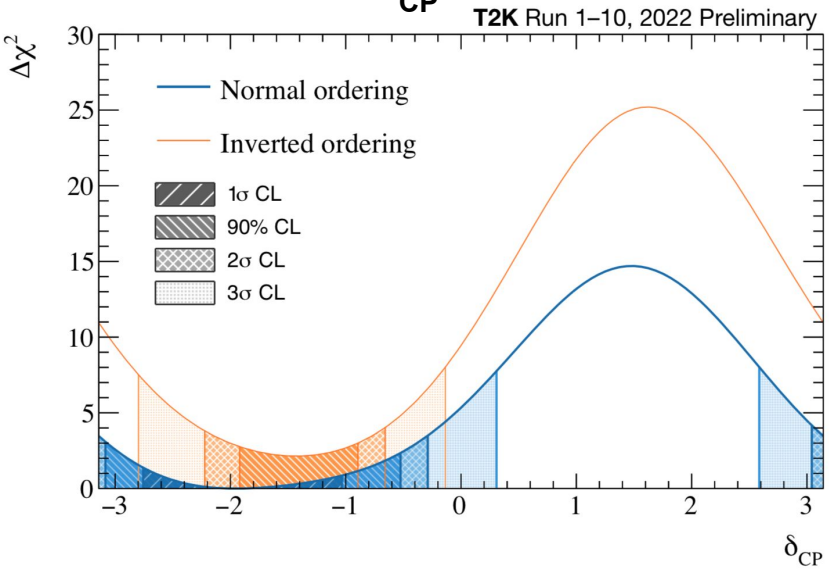


T2K oscillation measurements



World leading measurement of the atmospheric parameters!

and of δ_{CP} !



Large region of δ_{CP} values excluded at 3σ

CP conservation excluded at 90%

Preference for Normal Ordering

Why neutrino cross sections matter for the oscillation analysis?

To extract the **oscillation probability**, we compare the **number of detected neutrino interactions** in the **near detector** to the **far detector**:

$$\frac{N_{events}^{far}(\vec{x})}{N_{events}^{near}(\vec{x})} = \frac{\sigma(E_\nu,\vec{x}) \otimes \Phi^{far}(E_\nu) \otimes D^{far}(\vec{x}) \otimes P_{osc}(E_\nu)}{\sigma(E_\nu,\vec{x}) \otimes \Phi^{near}(E_\nu) \otimes D^{near}(\vec{x})}$$

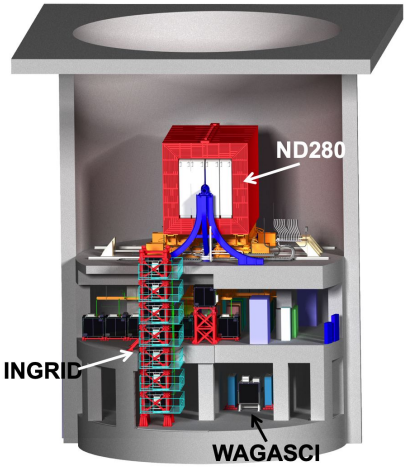
Event rates determined by the **neutrino interaction probability** (cross section), the **neutrino flux** and the **detector effects**. Any uncertainties on these quantities will affect the predictions of N^{far} and N^{near} and thus the precision of the oscillation probability measurements

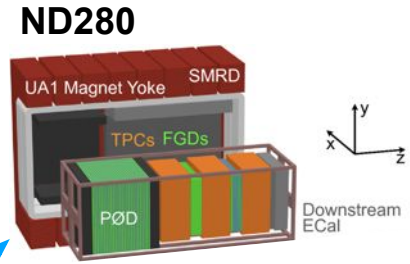
In the 2022 T2K oscillation analysis: total systematic uncertainty of 5.2% (ν_e appearance in neutrino mode), ~4% comes from the uncertainty on neutrino interaction processes

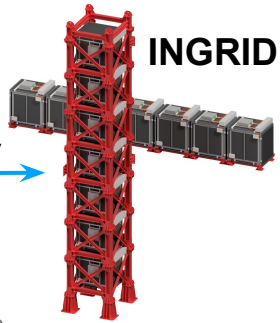
Currently in T2K the dominant systematics come from uncertainty on neutrino cross sections
⇒ let's measure neutrino cross sections @T2K near detectors!

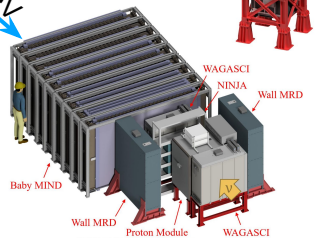
NOTE: today not the major problem, we have ~100 ν_e appearance events... but this will become a problem for HK (where we expect more than 2000 ν_e appearance events)

T2K cross-section measurements









WAGASCI/ BabyMIND

E_ν = 0.6 GeV 2.5° off-axis

E_ν = 1.1 GeV on-axis

E_ν = 0.9 GeV 1.5° off-axis

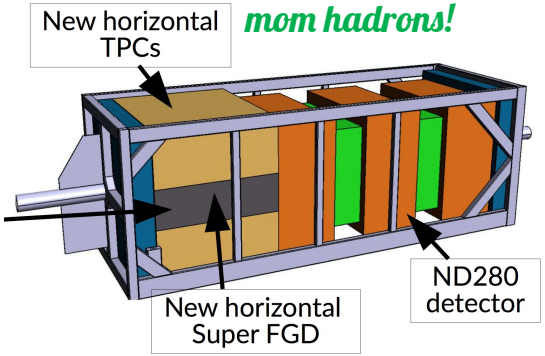
T2K world-leading experiment also in the ν xsec field!

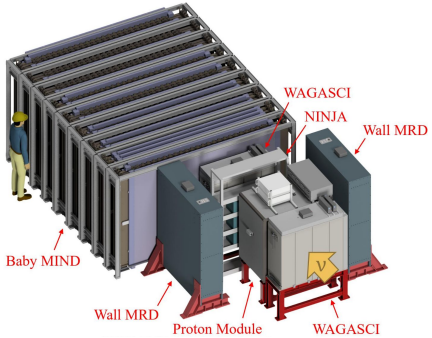
T2K near detector complex allows to measure neutrino cross sections:

- at **different off-axis**, i.e. different energies
- on **different targets**: Carbon, Oxygen, Iron,...
- with **different samples**: ν_μ , $\bar{\nu}_\mu$,ν_e , $\bar{\nu}_e$
- spanning **different final state topology** (CC0pi, CC0pi1p, CC1pi, CC1pi1p,...)
- **limiting model dependence** ⇒ this provide stable and **long-lived results** supported by **sophisticated data release**
- So far **>20 publications**: 6 CC-Inclusive, 3 ν_e, 12 CC0pi, 4 CC1pi

What T2K xsec measurements can teach to HK and DUNE?

++ on understanding nuclear effects and on low mom hadrons!



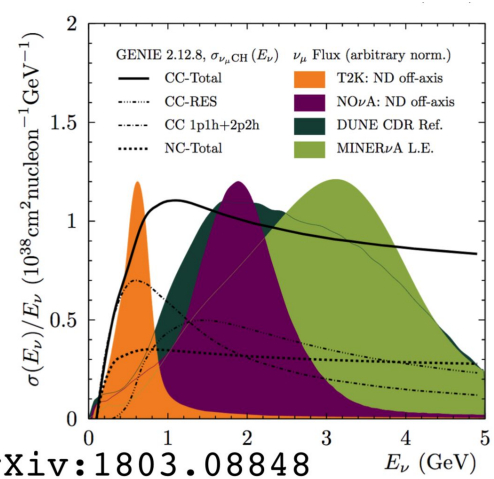


++ on understanding the water target (same as SK) and the energy dependence of xsec

Previous **focus on dedicated CC0pi measurements,** the most abundant channel in T2K (12 publications + 5 ongoing). **Sophisticated systematics model** developed for the oscillation analysis (based on spectral function)

Now moving to **characterise the CC1pi channel**, the 2nd most abundant in T2K (4 publications + 5 ongoing) - known to be mismodeled

Expecting even more exciting measurements thanks to the ND280-Upgrade and WAGASCI/BabyMIND!



arXiv:1803.08848

HK - same neutrino beam, same near detectors (to begin with), same far detector technology ⇔ obvious synergy!

DUNE - different spectra and target, but **T2K characterisation and parameterisation of CC0pi and CC1pi** interactions can be beneficial. We expect increased sensitivity to the **hadronic system** with the ND280 upgrade (also neutrons!). Also, xsec **extraction techniques and tools** could help.

What T2K is going to discuss during this workshop?

Tuesday morning: cross section extraction method (unfolding)

Cross-section extraction using template fitting in T2K cross-section measurements — *Margherita Buizza Avanzini et al.*

500/1-001 - Main Auditorium, CERN — 11:30 - 11:50

Binned log-likelihood template fitting with T2K — *Nick Latham*

500/1-001 - Main Auditorium, CERN — 12:00 - 12:15

Tuesday afternoon: looking forward ND280 Upgrade (forward folding?)

Unbiased reconstruction of calorimetric variables in cross-section analyses — *Katharina Lachner*

31/3-004 - IT Amphitheatre, CERN — 14:25 - 14:40

Thursday morning: dealing with the efficiency correction

Dealing with high dimensional efficiency corrections in T2K's cross-section measurements — *Sam Jenkins et al.*

222/R-001, CERN — 09:00 - 09:20

+ a series of other T2K collaborators giving more general or theory-related talks