New features in the T2K near detector constraints for the oscillation analysis (on behalf of the T2K collaboration)

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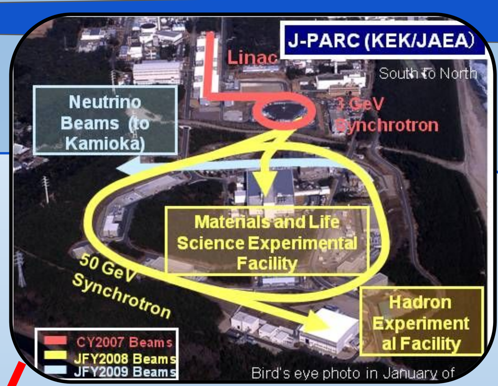
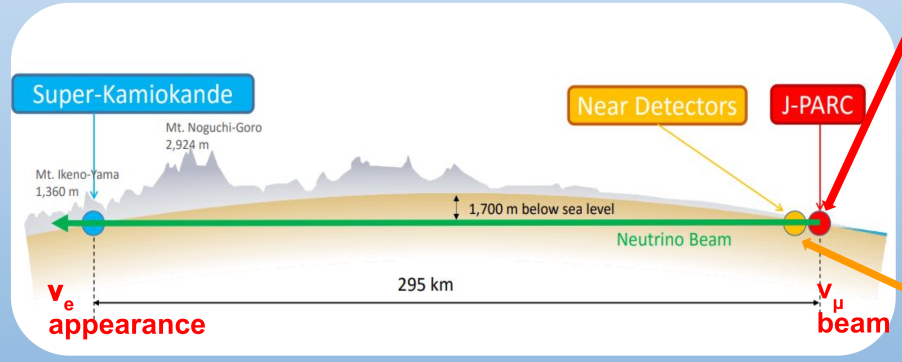
What's T2K ?



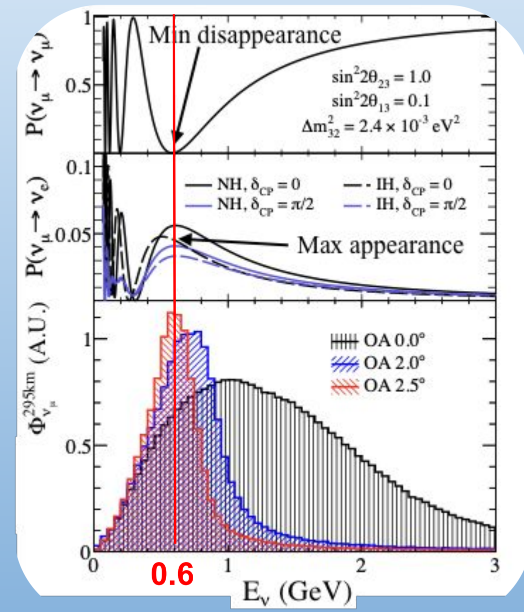


- Tokai to Kamioka - Long baseline neutrino oscillation experiment
- Near detector data used to tune flux and ν interaction model
- Far detector data used to measure the oscillation parameters. We focus on θ_{23}, Δm^2_{32} and δ_{CP}

Neutrino oscillation

We focus on ν_μ disappearance & ν_e appearance (and their antineutrino counterparts) ! This allows to measure the atmospheric oscillation parameters (θ_{23} and Δm^2_{32}) and to access the measurement of δ_{CP} → first hints of CP violation in the lepton sector

if $\delta \neq 0$ and $\delta \neq \pi$, $P(\nu_\alpha \to \nu_\beta) \neq P(\bar{\nu}_\alpha \to \bar{\nu}_\beta)$



$$P(\nu_\mu \to \nu_e) \simeq \sin^2(2\theta_{13})\sin^2(\theta_{23})\sin^2(\Delta m^2_{32}L/4E) \mp O(\sin(\delta_{CP}))$$

$$P(\nu_\mu \to \nu_\mu) \simeq 1 - \sin^2(2\theta_{23})\sin^2(\Delta m^2_{32}L/4E)$$

T2K oscillation analysis strategy

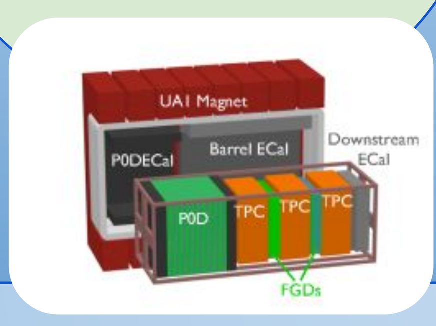
- From Near detector fit to the Far detector prediction

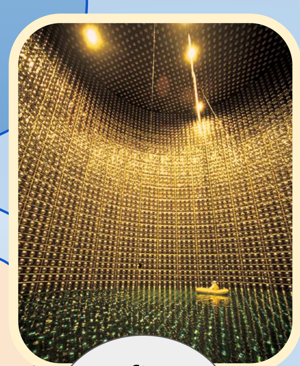
Flux prediction
Proton beam measurement, production of hadrons

Neutrino interaction
Cross-section model

before oscillation !

ND280
Near detector
ν_μ and $\bar{\nu}_\mu$ to constrain flux and cross-section models





after oscillation

Prediction at Super-Kamioka (Far detector)
Combine Flux and cross-section

extraction of oscillation parameters

SK measurements
Selection of neutrinos candidates (ν_μ, ν_e, $\bar{\nu}_\mu$ and $\bar{\nu}_e$)

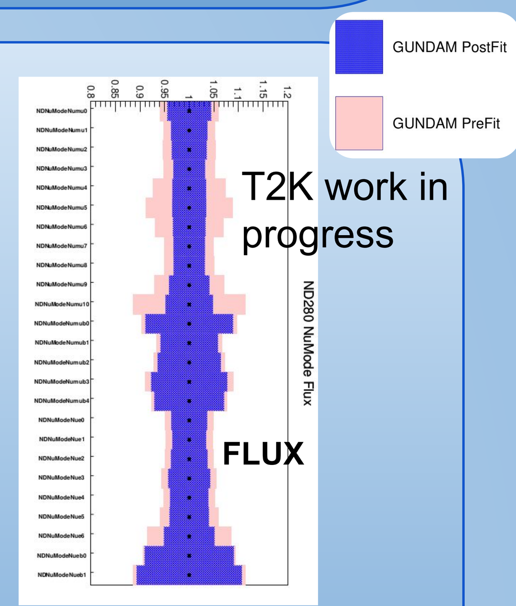
ND fit frameworks

INPUTS
samples
systematics

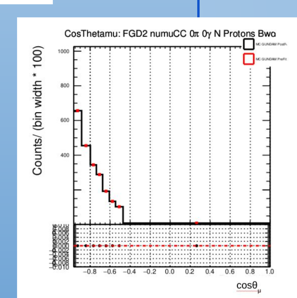
Bayesian approach
MaCh3
MCMC using Metropolis-Hastings algorithm

GUNDAM NEW !
New fitter used for OA 2024 !
Gradient descent fit using Minuit2
Frequentist approach

Event rates
LLH scans
postFit pars values & errors



T2K work in progress

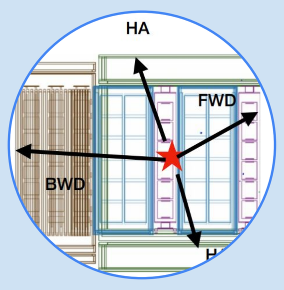


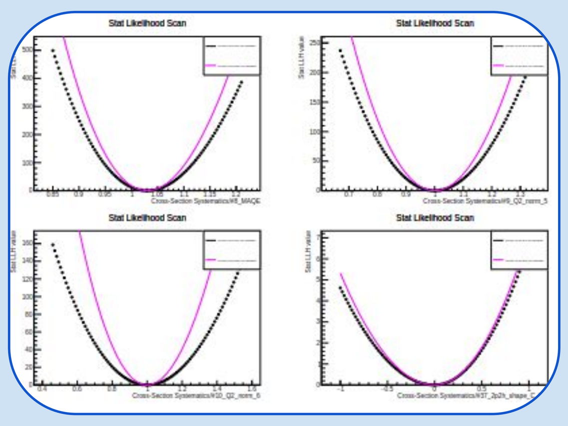
GUNDAM output examples

Novelties in the ND fit for the 2024 oscillation analysis

1

- Improved acceptance (new 4π selection)
- Improved constraints on the cross-section systematics
- Expanded phase space in a previously poorly explored region (gain ~ 13% statistics thanks to High-angle and backward going tracks)

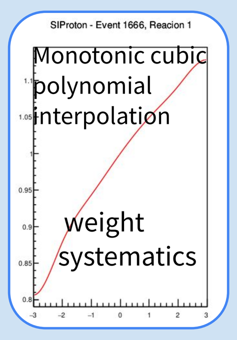


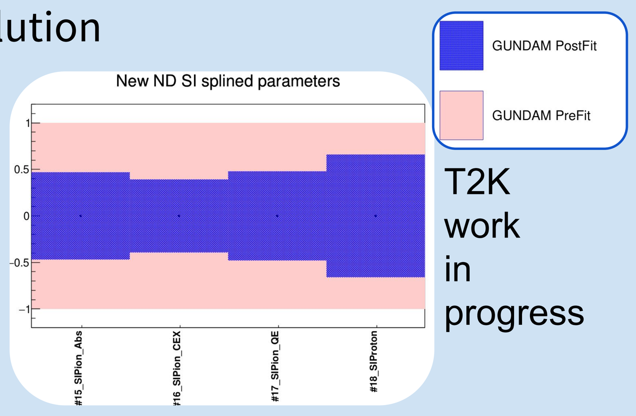


Likelihood scans illustrating the better sensitivity to some cross-section systematics using the new 4π sample selection.

2

Weight systematics : each event associates weight (e.g. Pion and Proton Secondary Interaction)
Variation systematics : affect observable quantities (muon momentum and event topologies), e.g momentum resolution



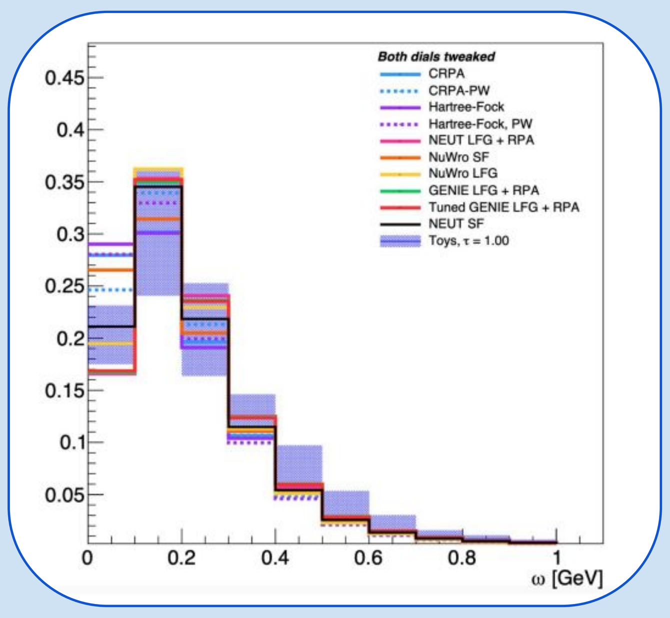


T2K work in progress

First new parameterisation of the weight systematics adopted: thanks to the use of response functions, intrinsic detector parameters can now be directly constrained. Previous approach only used a covariance matrix encoding the overall effect of all detector systematics on the event rate.

3

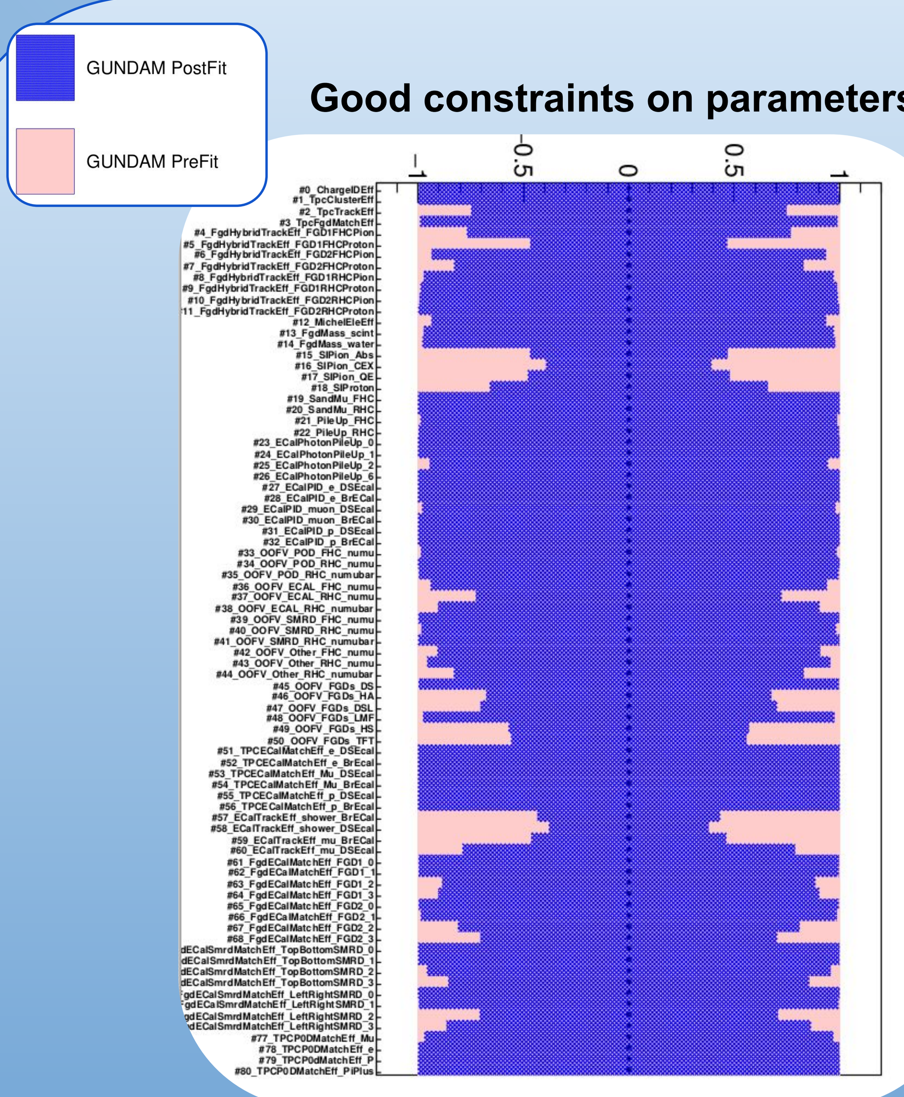
- New neutrino interaction parameters → allows to add enough freedom to the model especially in the low Q2 region



New systematics parameterisation to cover model disagreements at low energy transfer

GUNDAM Asimov fit comparison for the 2024 ND fit

Good constraints on parameters !

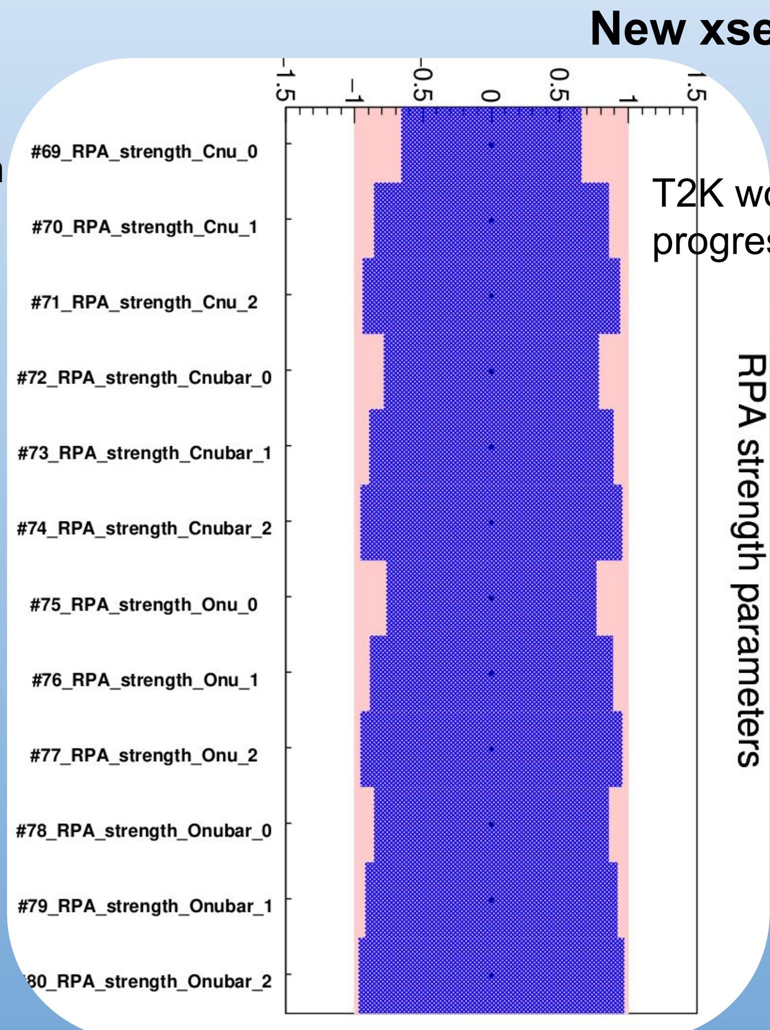


T2K work in progress

New ND splined parameters

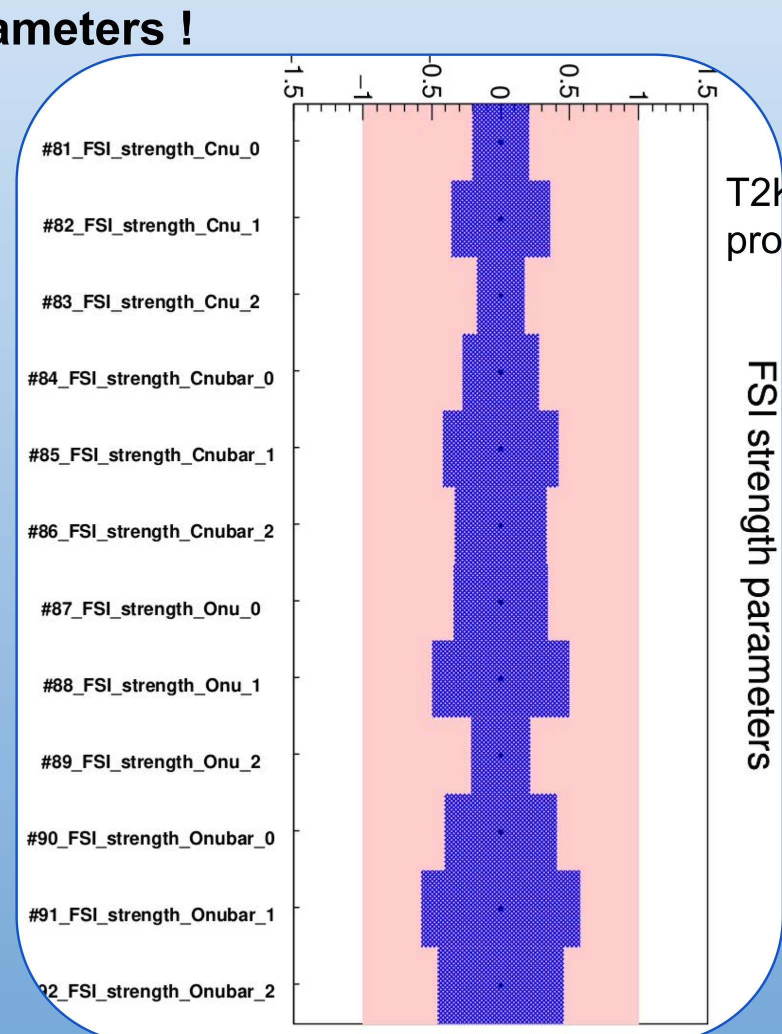
New Detector parameters !

New xsec parameters !



T2K work in progress

RPA strength parameters



T2K work in progress

FSI strength parameters

Next steps :

- Study robustness of the cross-section model
- P-value validation
- Data fit