1. Motivations (FAQ)
Understanding neutrino-nucleus interactions is essential for the precise measurement of neutrino \( \nu \) oscillations at long-baseline experiments, such as T2K.

Why the oxygen target? The T2K detector uses water modules alternating with scintillator layers.

Why the C/O ratio? The T2K near detector (ND280) has scintillator and water targets.

Why CC0 interactions? CC0 interactions dominate at T2K. Not possible to identify them event-by-event (nuclear effects).

Reduce model dependence by event.

Why CC0 with external measurements. The T2K far detector, Super-Kamiokande use water: measurement of \( \nu \) cross sections on oxygen required!

2. The T2K near detector: ND280
Near Detector complex (ND280) located at 280m from the production target, 2.5° off-axis as Super-Kamiokande.

For this analysis we use:
- 3 Time Projection Chambers (TPC) for momentum reconstruction and particle identification (NIMA 637, 25 (2011))
- 2 Fine-Grained Detectors (FGD1 and FGD2) as a target (NIMA 694, 1 (2013)). Both are made of C46 scintillator bars alternately oriented in the x and y directions for a 3D tracking. FGD2 also contains water modules alternating with scintillator layers.

4. Simultaneous extraction of O and C sections
For the first time we combine FGD1 and FGD2 data to simultaneously extract the O and C double differential flux integrated cross sections as a function of the muon kinematics \((c_{\nu}, p)\).

Base concept of the analysis:
1. samples reconstructed in FGD2-X layers are oxygen-enhanced
2. samples reconstructed in FGD2-Y and FGD1 are carbon-enhanced

Binned likelihood fit
Via a binned likelihood fit, carbon and oxygen interactions are simultaneously fitted to the number of selected events, in all the signal and background samples.

Key features
- Unconstrained fit parameters that estimate the signal in each bin -> minimize the model dependence
- Detector-related and theoretical parameters included as nuisance parameters -> reduce the systematic
- FGDo samples effectively constrain Carbon interactions -> reduce the anti-correlation O-C and the related uncertainties!
- Data-driven regularization (arXiv:1802.05078) -> minimize the anti-correlation between adjacent bins (optional!)

Reduced anti-correlation between \( c \) and \( o \) !

FGD2+FGD1, \( O/C \) and \( o \leftrightarrow c \) !

5. Blind analysis: fit validation and pseudo data studies
Uncertainties estimation

- Nominal Monte Carlo is NEUT (5.3.2).
- Detector, vertex migration, flux and model systematic errors are evaluated via toy experiments. Toys are used to vary priors, same technique will be used also for data.
- The final cross section is the mean value obtained over \( N_{\text{trend}} \) and the standard deviation is taken as an uncertainty.
- Considering detector, flux, model and statistical uncertainties.

\( \nu_e \) cross section on Oxygen (prior: NEUT, pseudo data: GENIE)

\( \nu_e \) cross section on Carbon (prior: NEUT, pseudo data: GENIE)

\( \nu_e \) cross section ratio: O/C (prior: NEUT, pseudo data: GENIE)

Conclusions: FITter works correctly! unbias soon! Stay tuned!