The ROOT files here contain the data-release for the T2K flux-integrated phase-space restricted differential cross-section measurements of interactions which leave no pions in the final state (CC0pi), as presented in *PRD XYZ*. This paper contains **three separate analyses:**

- **A multi-differential measurement** of CC0pi interactions binned in: the number of protons above 500 MeV; the cosine of the outgoing muon angle with respect to the incoming neutrino; the cosine of the highest momentum outgoing proton angle (if one was seen) with respect to the incoming neutrino; and the momentum of the highest momentum outgoing proton.

- An analysis that measures three CC0pi cross sections each in bins of a particular **single transverse variable.** The kinematic phase-space measured by this analysis is restricted such that it requires: at least one proton in the final state with momentum between 450 MeV and 1 GeV; the cosine of the highest momentum outgoing proton angle momentum proton angle with respect to the incoming neutrino is above 0.4; the outgoing muon momentum is above 250 MeV; and the cosine of the outgoing muon angle with respect to the incoming neutrino is above -0.6.

- An analysis that measures three CC0pi cross sections in bins of a particular variable characterising **proton inferred kinematic imbalance within bins of outgoing muon kinematics.** The kinematic phase-space measured by this analysis is restricted such that it requires: at least one proton in the final state with momentum above 450; and the cosine of the highest momentum outgoing proton angle momentum proton angle with respect to the incoming neutrino is above 0.4.

It should be noted that all three of these analyses exploit mostly the same data. The exception to this is that the 0th proton multiplicity bin of the multi-differential analysis (explained below) is almost independent from the other results.

The multi-differential data release (multidif_results.root)

The cross-section is quoted in units of 10E-39 cm^2 per target nucleon. In the histograms with linearized binning and in the 2D histograms the bin content have not been divided by the bin width (area). In the other cases, the bin content is always divided by the 1D bin width along the x axis, without considering further binning on other variables. (So, for instance, the plots of cross-section as a function of momentum are in units of 10E-39 cm^2 per target nucleon per GeV)

- Result (a TH1D) contains the extracted cross section in linearised binning as provided in the text file multidif_binMap.txt (in brief: the first 60 bins correspond to the 0 proton sample, the bins from 61 to next-to-last bins correspond to one proton sample and the last bin correspond to the sample with 2 or more protons). These bins have not been normalised by the width.
- CovarianceMatrix (a TH2D) contains the extracted covariance in the same binning as Result. This is measured in units of 10E-78 cm^4.

These two objects contain the entire analysis result but to facilitate easy comparisons extra information is contained in the following sub directories.

The **NoProtonsAbove500MeV** directory contains the 2D results for the sample which has no protons above 500MeV (the 0th proton multiplicity bin). This contains:

- ResultInMuonCosTheta (a TH1D) contains the 1D differential cross section in bins of the cosine of the outgoing muon angle. Each bin is normalised by its (1D) width.
- MuonCosThetaSlice_X (10 TH1Ds) which each contain a 1D slice of the cross section in muon angle (each corresponds to a bin in ResultInMuonCosTheta) in bins of the outgoing muon momentum. Each bin is normalised by its (1D) width.
- FullBinnedResult_poly (a TH2Poly) which contains the full 2D result within the 0th proton multiplicity bin in the form of a TH2Poly. These bins have not been normalised by the width. The uncertainties are not included.

The **OneProtonAbove500MeV** directory contains the 3D results for the sample with 1 proton above 500MeV (the 1st proton multiplicity bin). This contains:

- ResultInMuonCosTheta (a TH1D) contains the 1D differential cross section in bins of the cosine of the outgoing muon angle. Each bin is normalised by its (1D) width.

- MuonCosThetaSlice_1D_X (4 TH1Ds) which each contain a 1D slice of the cross section in muon angle (each corresponds to a bin in ResultInMuonCosTheta) in bins of the outgoing proton angle. Each bin is normalised by its (1D) width.
- MuCThSlice_X_PCThSlice_Y (4 TH1Ds) which each contain a 1D slice of the cross section in muon angle and in proton angle in bins of outgoing proton momentum. Each bin is normalised by its (1D) width.
- MuonCosThetaSlice_X_poly (TH2Polys) which each contain a slice of muon angle binned in the momentum of outgoing proton and its angle. These bins have not been normalised by the width. The uncertainties are not included.

The **ProtonMultiplicity** directory contains the result integrated over everything but the proton multiplicity bins.

- Result (a TH1D) contains the extracted cross section in bins of proton multiplicity (number of protons above 500 MeV). The final bin corresponds to 2 or greater number of protons seen above 500 MeV.
- CovarianceMatrix (a TH2D) is the covariance between bins of proton multiplicity

The single transverse variable data-release (datResults(_noreg).root, dphitResults(_noreg).root, dptResults(_noreg).root)

datResults.root, dphitResults.root and dptResults.root contain the regularised results for cross sections extracted as a function of δα_T, δφ_T and δp_T respectively

datResults.root, dphitResults.root and dptResults.root contain the unregularised results in the same format.

- Result (a TH1D) contains the cross section measured in units of cm^2 per target nucleon per GeV (rads) for δp_T (δα_T, δφ_T). Each bin has been normalised by its width.
- Covariance_Matrix (a TH2D) contains the covariance in the same binning as Result
- Correlation_Matrix (a TH2D) contains the correlation matrix in the same binning as Result

The user has the choice of using the regularised or unregularised results. When deconvolving the detector smearing from the data, an unregularised process is unbiased but can give large-correlations between adjacent bins in the result, which will tend to “zig-zag” around the truth. The application of regularisation uses prior knowledge of the true signal distribution in order to smooth the result, thereby obtaining a more diagonal correlation matrix, at the cost of some bias. In this analysis the regularisation strength is chosen (based on data rather than toy simulation studies) to balance minimal bias with a reasonable smoothing effect using the L-Curve method discussed in the paper.

Overall the unregularised result is unbiased but is difficult to interpret without the accompanying correlation matrix, whilst the regularised result contains a small bias but has less important off-diagonal terms in the correlation matrix.

It should be noted that the widely used iterative unfolding methods, such as that used in the proton inferred kinematic analysis, are natively regularised (the unregularised result is one with infinite iterations) where the often-used single iteration case gives maximal bias (equivalent to a much higher regularisation strength than is used in this analysis).

In summary, the user is advised to use the *unregularised results* when attempting to form a quantitative conclusion, for example when using the whole measurement to set constraints on model parameters as part of a likelihood fit or when, in an an assessment of model-result agreement, a chi2-like metric is considered more important than the data-result histogram. The user is instead advised to use the *regularised results* when comparing to model predictions or results “by eye” or when trying to isolate model-result discrepancies to specific kinematic regions (this is almost always the case when showing a histogram of the cross-section results).

The proton inferred kinematic imbalance data-release
(infkResults.root)

The cross-section is measured in units of 10^-39 cm^2 per target nucleon per GeV (degrees) for Δp, |Δp| (ΔΘ). Each bin had been normalised by its width in the inferred proton kinematic observable (but not in muon kinematics).

Each object in infkResults.root is labelled with a _p, _a or _tp which corresponds to the measurements of Δp, ΔΘ or |Δp| respectively.

- result_X (TH1Ds) contain the cross sections in linearised binning. These are arranged as 7 bins in muon kinematics (as enumerated in section IV.G of the publication) which each contain either 7 bins of Δp or |Δp| or 5 bins of ΔΘ.
- resultBinY_X (TH1Ds) contain the cross section in bins of the inferred proton kinematic observables within the Yth muon kinematic bin (as enumerated in section IV.G of the publication).
- cov_X (TMatrixDs) are the covariance matrices in the same binning as result_X.
- cor_X (TMatrixDs) are the correlation matrices in the same binning as result_X.