

Towards the cross-section measurement of the $\bar{\nu}_\mu$ CC single π -production in the T2K near detector

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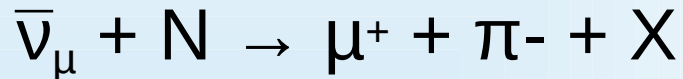
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19.02.2021

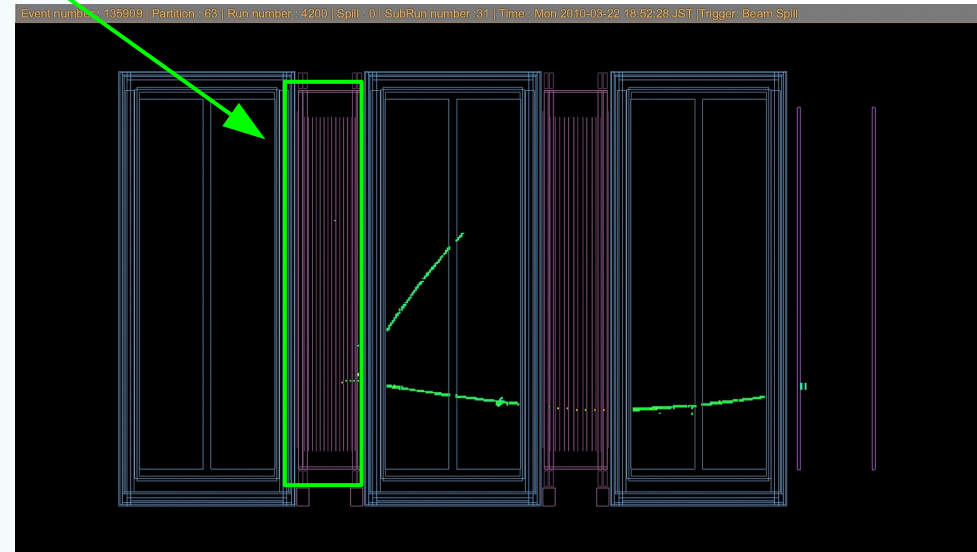


CC1 π^- cross-section measurement

- The signal for my cross-section are events with CC1 π^- topology in ND280 subdetector – scintillator **FGD1** (CH target).



- Double differential in μ^+ momentum and $\cos\theta$. Restricted phase-space (see backup).
- Background in CC quasi-elastic (CCQE) sample in oscillation analysis.
- Might be used in future oscillation analysis as a separate sample.
- Few measurements of $\bar{\nu}_\mu$ single pion production so far.
- Validation of neutrino interaction models.

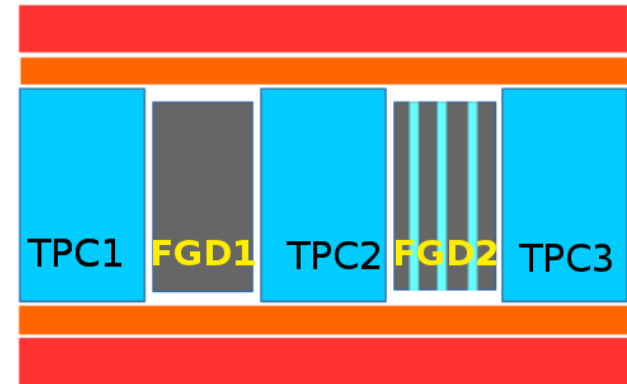


More ND280 details:
M. Guigue plenary talk,
*The T2K Experiment:
Status, Results and
Prospects*

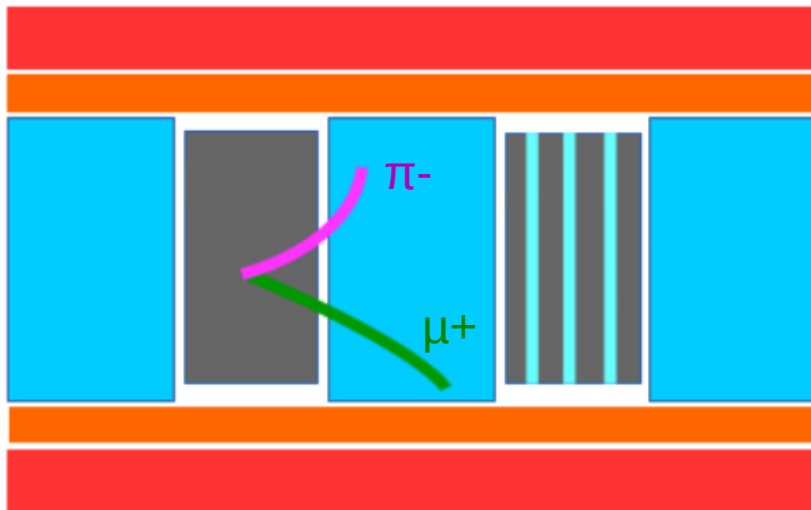
Signal selection

- Selection based on event signature in the tracker (inner part of ND280).
- μ^+ track always required
- **Two signal samples:**

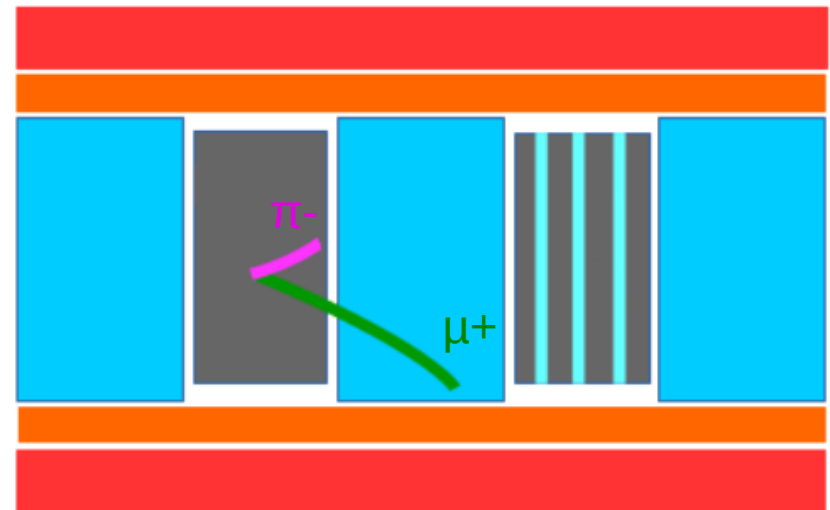
Tracker



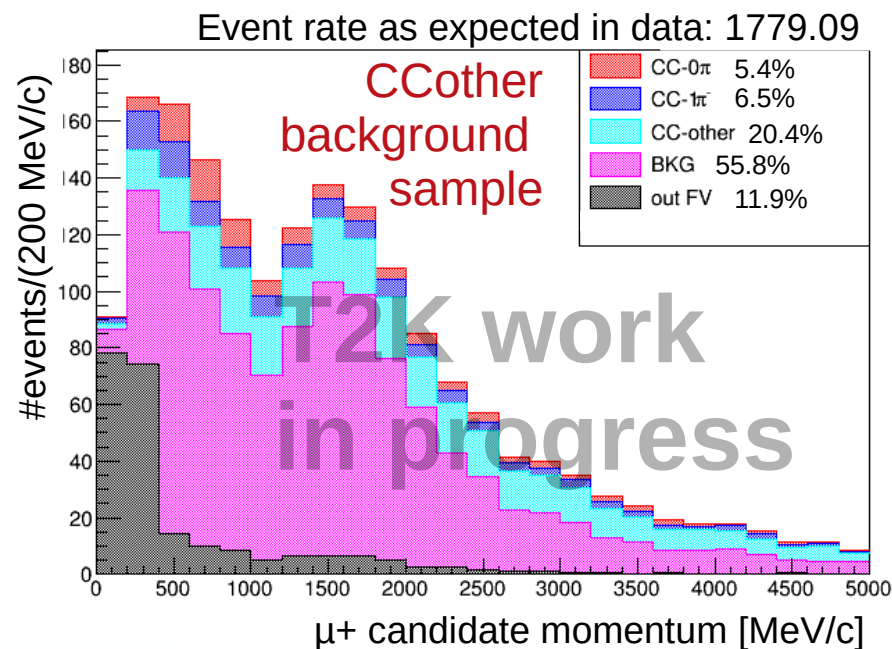
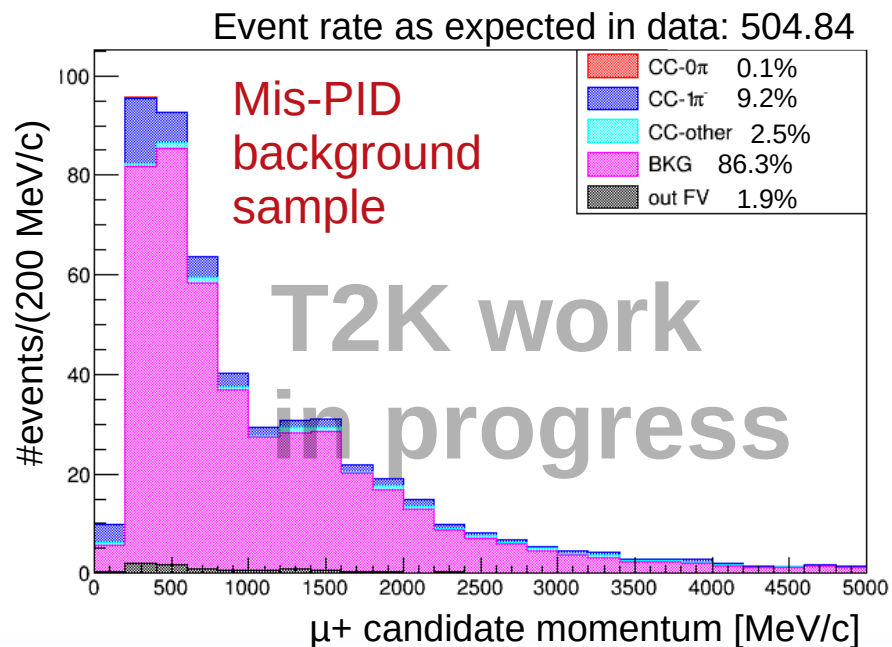
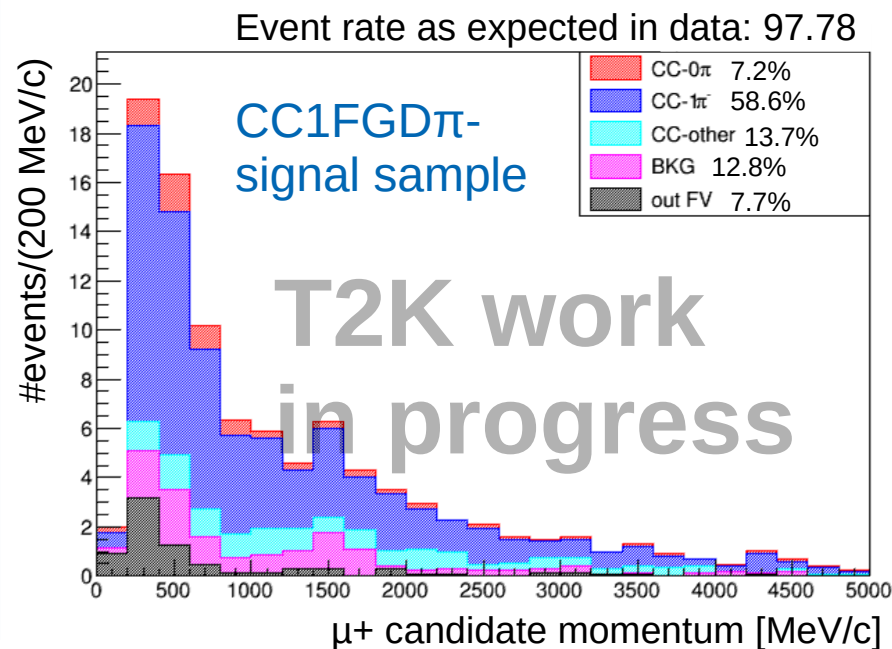
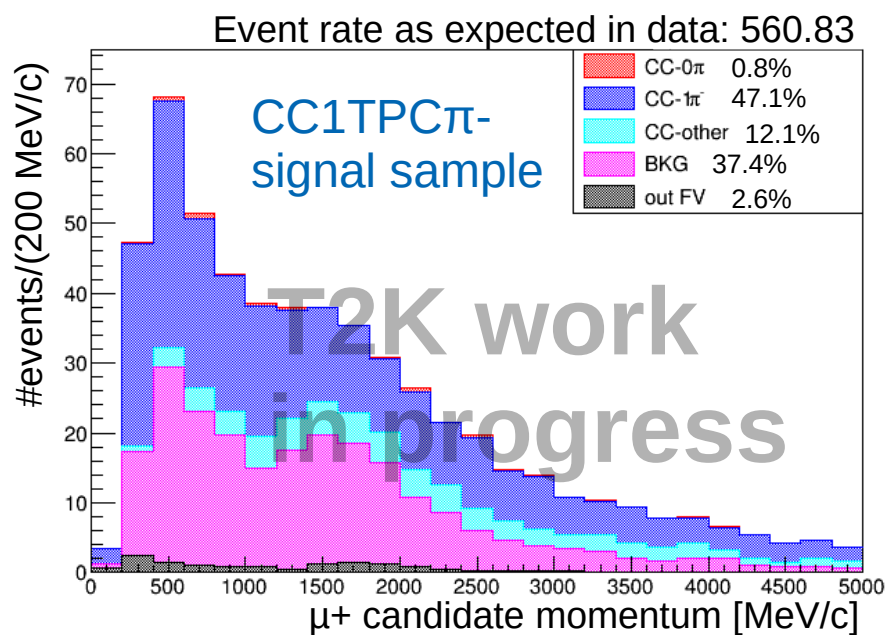
Single TPC π^- track



Single isolated FGD π^- track



- For the cross-section extraction two **signal samples** and two **background control samples** are used.



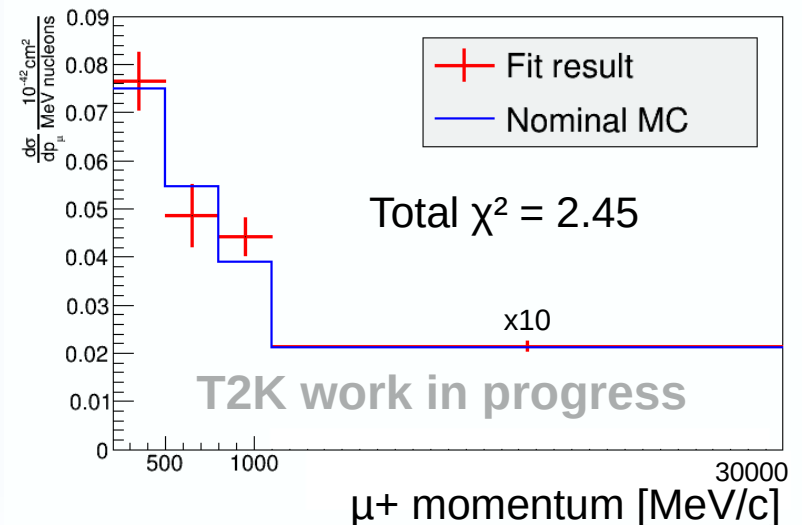
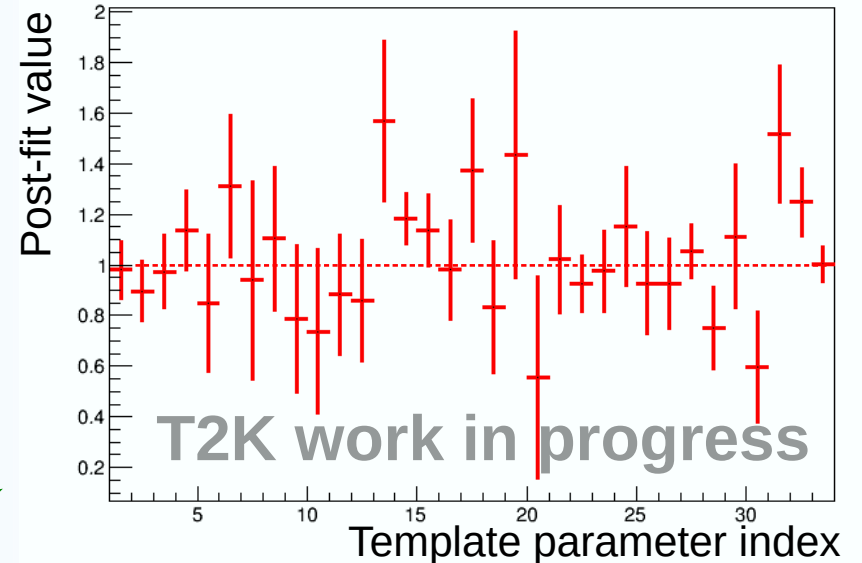
Likelihood Fitter

- The extraction of the cross-section will be done with the binned likelihood fitter.
- $N_i^{\text{signal}} = c_i N_i^{\text{MC signal}}$
 - N_i^{signal} – number of signal events in the bins of true variable
 - $N_i^{\text{MC signal}}$ – number of MC events in the bins of true variable
 - c_i – main free parameters of the fit (**template parameters**)
- MC predictions depend on **template** and **nuisance parameters** (flux, det syst, interaction model).
- Cross-section reported in **true physical variables** → **true phase space**.
 - True PS divided into 33 bins → 33 template parameters c_i .
- Detector measures **reconstructed variables** → **reconstructed phase space**.
- By fitting MC to reconstructed data the fit is able to obtain an unfolded result.

$$5 \quad \chi^2 = \chi_{stat}^2 + \chi_{syst}^2$$

Preliminary validation

- Before fitting MC to data method validation is needed.
- Example: fit a statistically fluctuated version of the nominal MC.
 - Post-fit template parameters.
 - Extracted cross-section in $\mu+$ momentum. (stat error only)



Conclusions

- Template likelihood fit method works properly in preliminary studies.
 - Data not yet used.
- Mock data tests ongoing with different MC generators.
- Data unblinding will follow after likelihood fit validation.

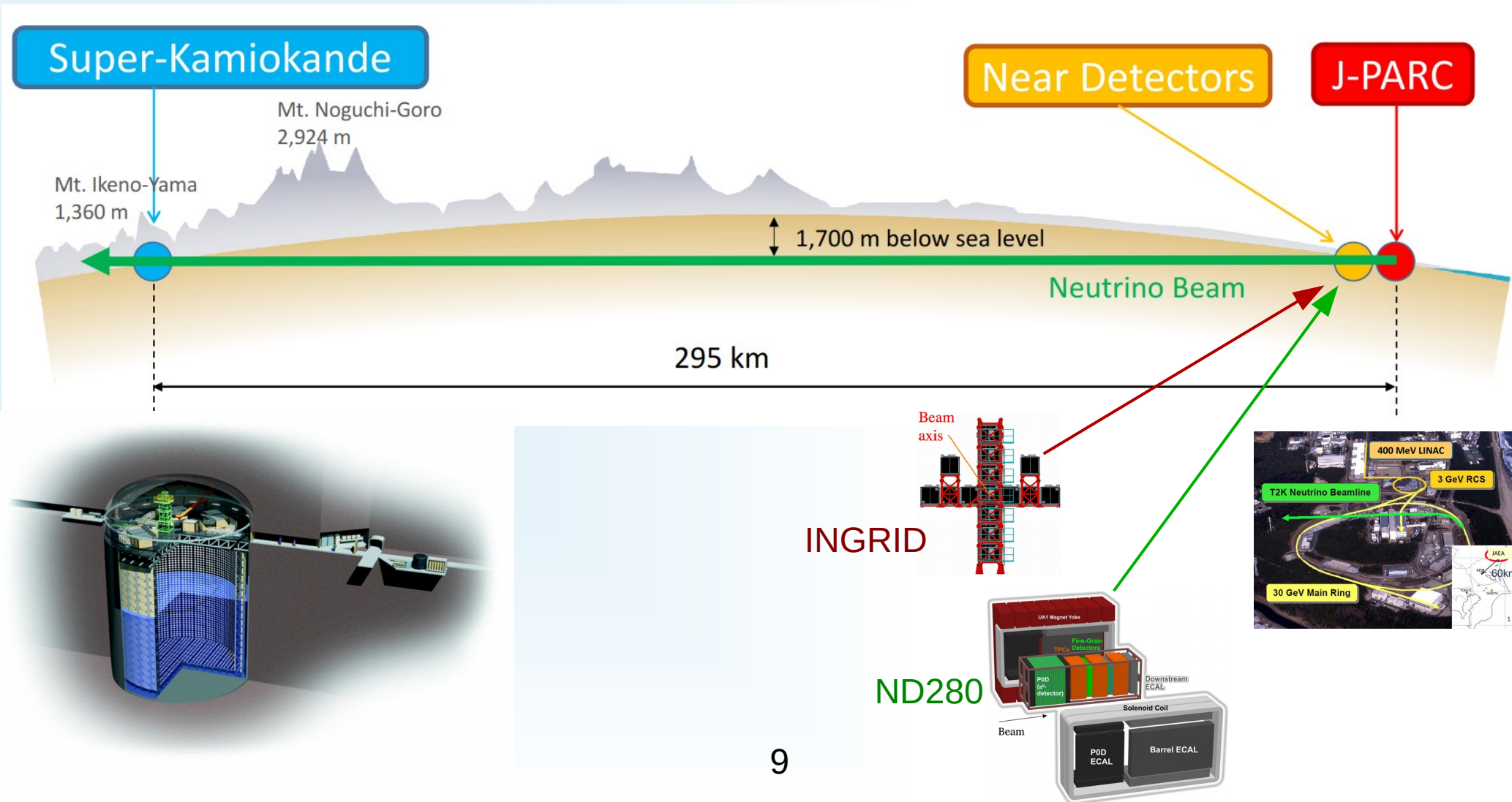
A series of overlapping, semi-transparent blue squares of varying sizes are arranged on the left side of the slide, creating a layered, geometric effect. The squares are centered vertically and extend from the top to the bottom of the slide.

Backup

T2K experiment

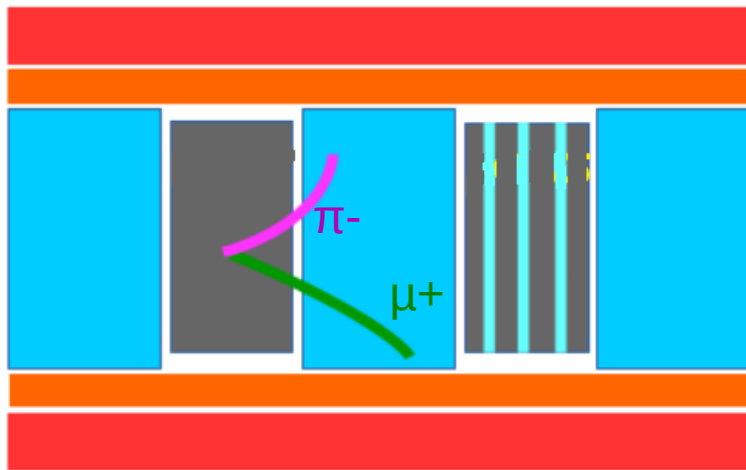


- T2K is a long-baseline neutrino experiment in Japan.



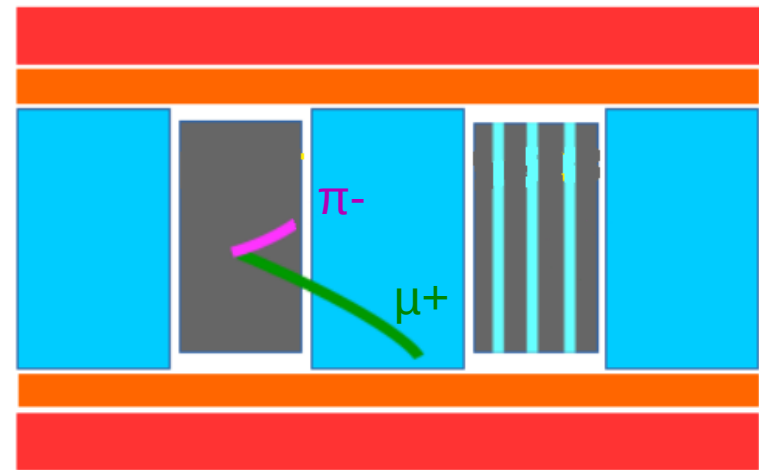
Signal selection

- Exactly one μ^+ (positive μ -like) track.
 - Particle identification based on dE/dx in TPC.
- No Michel electrons, π^+ or e^{\pm} tracks.
- **Two signal samples:**



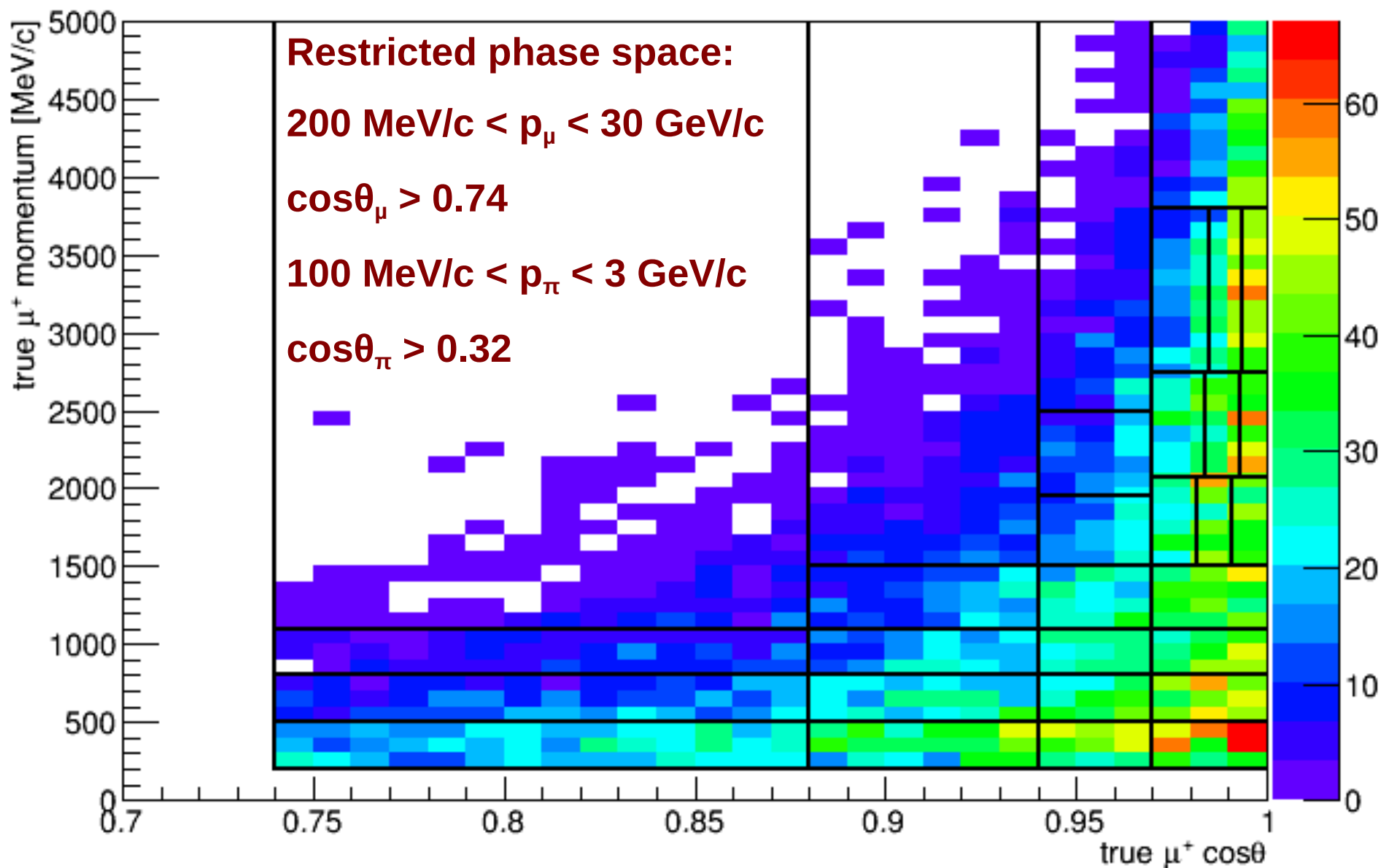
One TPC π^- track

Ending point of μ track more downstream than for π track (Z-range cut)



One isolated FGD track (with π -like FGD PID)

Phase space restrictions and binning



Likelihood Fitter

$$\chi_{stat}^2 = \sum_j^{recobins} 2 \left(N_j - N_j^{obs} + N_j^{obs} \ln \frac{N_j^{obs}}{N_j} \right)$$

N_j – estimated number of events for the reconstructed bin

N_j^{obs} – measurement

- At each iteration the fit changes the values of **template c_i parameters** and **nuisance parameters** until the best agreement is found.
- **Nuisance**: detector syst, flux, interaction model

Likelihood Fitter – more details

Truth bins \rightarrow

$$N_i^{MCsignal} = \sum_j^{\text{reco bins}} N_j^{MCsignal} t_{ij}^{det}$$

Transfer matrix \leftarrow

$$N_i^{MCBKG} = \sum_j^{\text{reco bins}} N_j^{MCBKG} t_{ij}^{det}$$

$$N_i = \sum_j^{\text{reco bins}} \left(c_i N_j^{MCsignal} + N_j^{MCBKG} \right) t_{ij}^{det} \sum_n w_{ni}$$

$$N_i = \sum_j^{\text{reco bins}} \left(c_i N_j^{MCsignal} + N_j^{MCBKG} \right) t_{ij}^{det} r_j^{det} \sum_n w_{ni} f_n$$

Template parameters

Nuisance parameters

Likelihood Fitter – more details

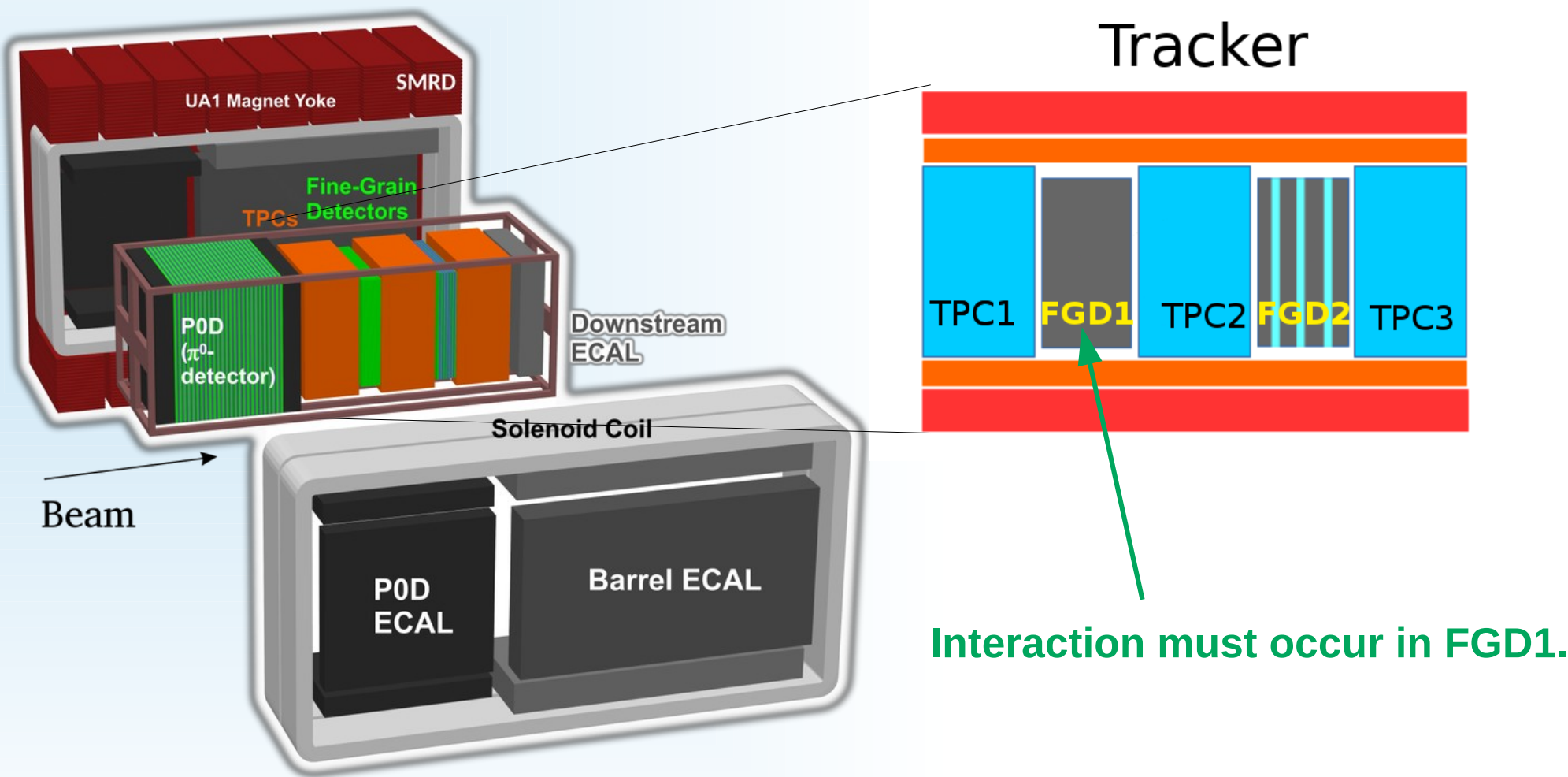
$$\chi_{\text{sys}}^2 = (\vec{r}^{\text{det}} - \vec{r}_{\text{prior}}^{\text{det}}) (V_{\text{cov}}^{\text{det}})^{-1} (\vec{r}^{\text{det}} - \vec{r}_{\text{prior}}^{\text{det}}) + (\vec{f} - \vec{f}_{\text{prior}}) (V_{\text{cov}}^{\text{flux}})^{-1} (\vec{f} - \vec{f}_{\text{prior}})$$

$$N_i = \sum_j^{\text{bins by topo}} \left[c_i \left(N_j^{\text{MC } CC0\pi} \prod_a^{\text{model}} w^{(a)}_{ij}{}^{CC0\pi} \right) + \sum_k^{\text{bkg reactions}} N_j^{\text{MC bkg } k} \prod_a^{\text{model}} w^{(a)}_{ij}{}^k \right] t_{ij}^{\text{det}} r_j^{\text{det}} \sum_n^{E_\nu} w_n^i f_n$$

Template parameters

Nuisance parameters

ND280



Difference of candidates reconstr. ending positions ($Z_{\text{end } \mu^+} - Z_{\text{end } \pi^-}$)

Applied cut: $Z_{\text{end } \mu^+} - Z_{\text{end } \pi^-} > -10 \text{ cm}$

