Timing Systematic

Small effect mostly because the ‘low res’ events’ direction is not used in fit. MC/Data difference for ‘Good timing’ events ~1% cf. ~4% for all events.
Hadronic models

344 kton-year S-G and FLUKA compared to ~5000 kton-year GCALOR

chi2/ndf
SLAC-G=50.6/46
FLUKA = 52.9/46
chi$^2$/ndf
SLAC-G = 25.1/20
FLUKA = 20.1/20
57% of selected events are QE. However, least data in this region to tune models. Take QE contribution error ~20%.
\[ -\ln \mathcal{L} = \sum_{\text{bins}(i)} (\alpha(N_\nu + \gamma N_{iQ^E}) + \beta N_i^\mu + \ln(N_{i\text{data}}!) - N_{i\text{obs}} \ln(\alpha(N_\nu + \gamma N_{iQ^E}) + \beta N_i^\mu)) \]

\[ + \left( \frac{1-\alpha}{\sigma_\alpha^2} \right)^2 + \left( \frac{1-\beta}{\sigma_\beta^2} \right)^2 + \left( \frac{1-\gamma}{\sigma_\gamma^2} \right)^2 \]
MC Sensitivity (25 kton-year)

$-\Delta \ln L$

$\Delta m_{23}^2 / \text{eV}^2$

- $\cos \theta_{\text{zenith}}$ with energy and $E_\mu/E_\nu$ binning
- $\cos \theta_{\text{zenith}}$ and energy binning
- $L/E$
- Up-down

Input Value