RECENT RESEARCH AND PLANS

Wing Yan Ma 马詠恩

Chung-Yao Chao Fellowship 2018 Interview

28th March 2018

Resume

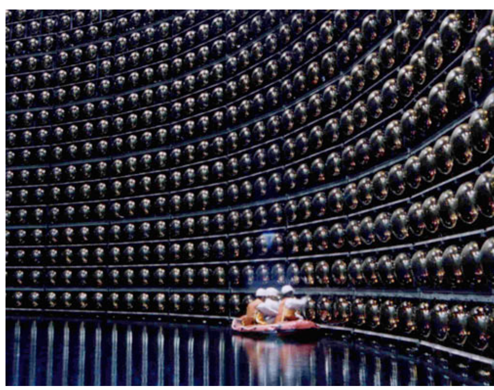
- Nationality: British, Hong Kong (speak 4 languages including Japanese)
- Obtained PhD degree in High Energy Physics at Imperial College London in November 2017, currently a visiting researcher at Imperial
- A collaborator of T2K, Hyper-K, Super-K
- Supervised by Morgan Wascko (International Co-spokeperson of T2K)
  - Thesis title: Five sample joint $\nu / \bar{\nu}$ oscillation analysis at T2K
- Major contributions in 3 published articles/proceedings. Currently in preparation for publishing recent neutrino oscillation results on PRL
- Regularly presented at collaboration meetings and international conferences/workshops (Nikhef, SLAC and Neutrino 2016 in London)

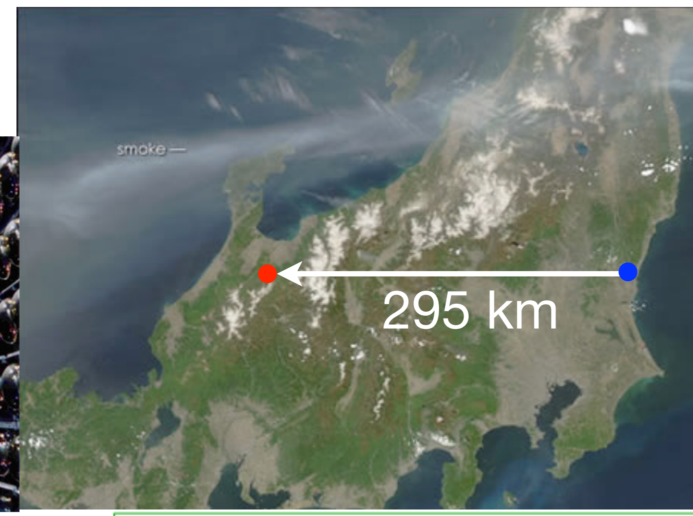
Available in full: http://www.hep.ph.ic.ac.uk/~wym109/CV_wym.pdf

My past work and achievements

Neutrino Oscillations at T2K

- T2K is a long-baseline accelerator neutrino experiment in Japan
- Designed to make precision measurements of neutrino oscillation by observing ν_μ disappearance and ν_e appearance





Far detector ν_μ events

$\nu_\mu \rightarrow \nu_X$ disappearance

$$P(\nu_\mu \rightarrow \nu_\mu) \approx 1 - \sin^2(2\theta_{23}) \sin^2\left(1.27 \frac{\Delta m^2 \times L}{E}\right)$$

Precise measurement of θ_{23} and $|\Delta m^2|$

Far detector ν_e events

$\nu_\mu \rightarrow \nu_e$ appearance

$$P(\nu_\mu \rightarrow \nu_e) \approx \sin^2(\theta_{23}) \sin^2(2\theta_{13}) \sin^2\left(1.27 \frac{\Delta m^2 \times L}{E}\right)$$

- Observation of ν_e appearance
- Measurement of θ_{13}

Measuring δ_{CP}

- Look for violation of CP symmetry by comparing $P(\nu_\mu \rightarrow \nu_e)$ and $P(\bar{\nu}_\mu \rightarrow \bar{\nu}_e)$

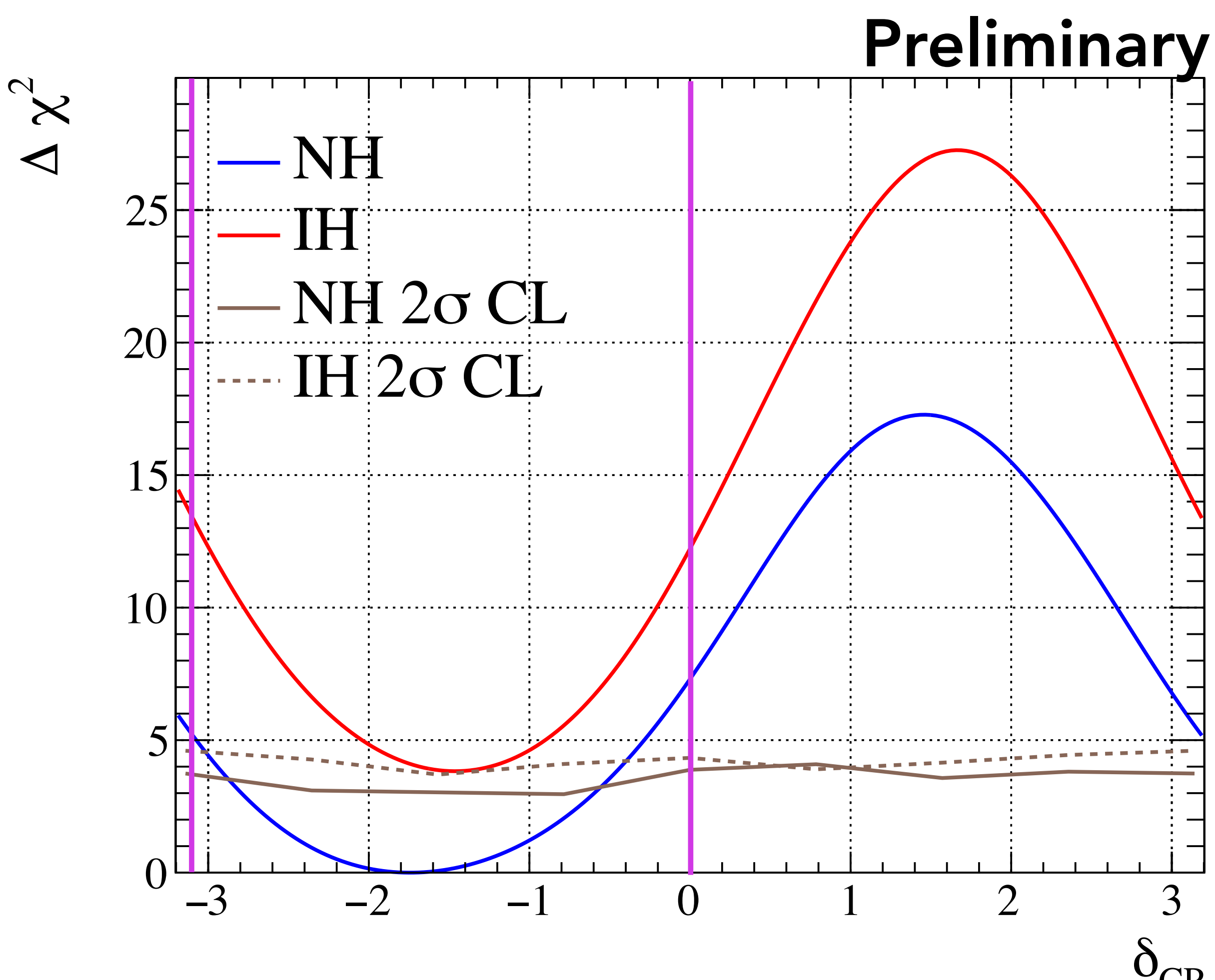
$$
\begin{aligned}
P(\nu_\mu \rightarrow \nu_e) = & 4c_{13}^2 s_{13}^2 s_{23}^2 \sin^2 \Delta_{31} \\
& + 8c_{13}^2 s_{12} s_{13} s_{23} (c_{12} c_{23} \cos\delta - s_{12} s_{13} s_{23}) \cos\Delta_{32} \sin\Delta_{31} \sin\Delta_{21} \\
& - 8c_{13}^2 c_{12} c_{23} s_{12} s_{13} s_{23} \sin\delta \sin\Delta_{32} \sin\Delta_{31} \sin\Delta_{21} \\
& + 4s_{12}^2 c_{13}^2 (c_{12}^2 c_{23}^2 + s_{12}^2 s_{23}^2 s_{13}^2 - 2c_{12} c_{23} s_{12} s_{23} s_{13} \cos\delta) \sin^2 \Delta_{21}
\end{aligned}
$$

replace δ by $-\delta$ for $P(\overline{\nu_\mu} \rightarrow \overline{\nu_e})$

Oscillation	$\delta > 0$	$\delta < 0$
$\nu_\mu \rightarrow \nu_e$	Suppressed	Enhanced
$\bar{\nu}_\mu \rightarrow \bar{\nu}_e$	Enhanced	Suppressed

1D δ_{CP} – T2K + Reactor fit

- T2K data show consistent preference for value near -2 radians
- Use unified approach by Feldman and Cousins to build CL intervals

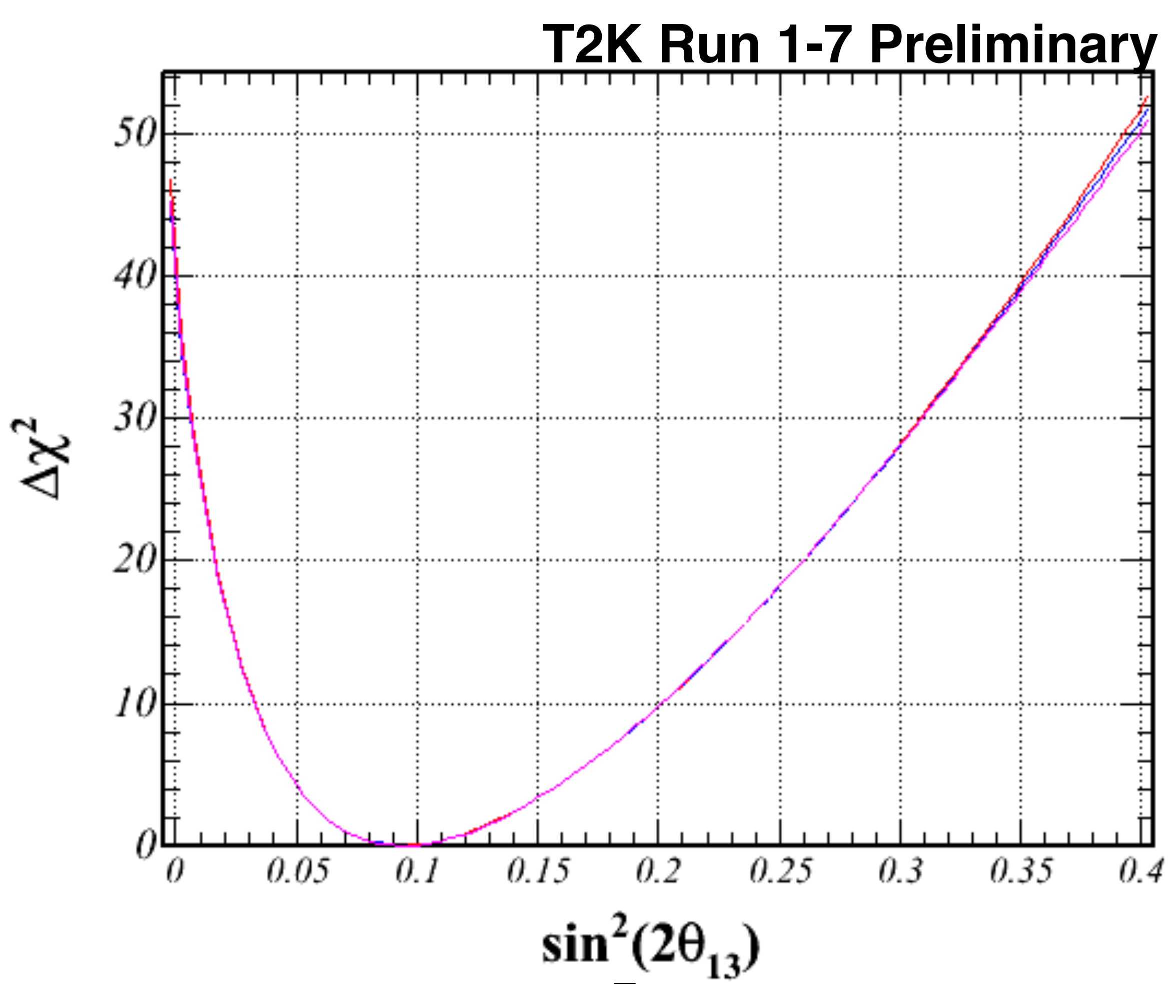


2σ intervals:
[-2.89,-0.56] (NH)
[-1.50,-1.27] (IH)

- CP conserving values (0,π) fall outside of the 2**σ** CL intervals
  - **CP conservation in neutrino sector excluded at 2σ!**
- I am the main analyser of one of the three analysis groups

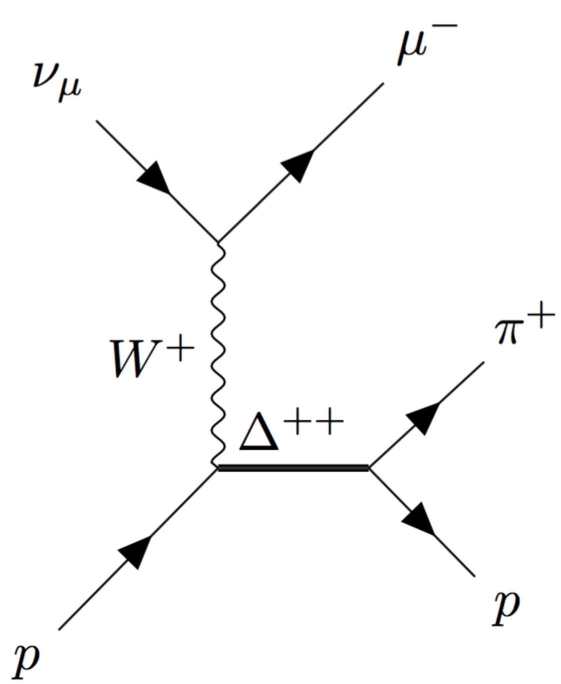
Adding new samples to OA

- I implemented the NCπ^0 sample selected at SK to p-theta code
- Could constrain NCπ^0 background in signal (1Re) sample
- I re-evaluate SK detector error and FSI+SI error to include π^0 systematics
- Look for potentially ignored systematic effects, important for future analyses

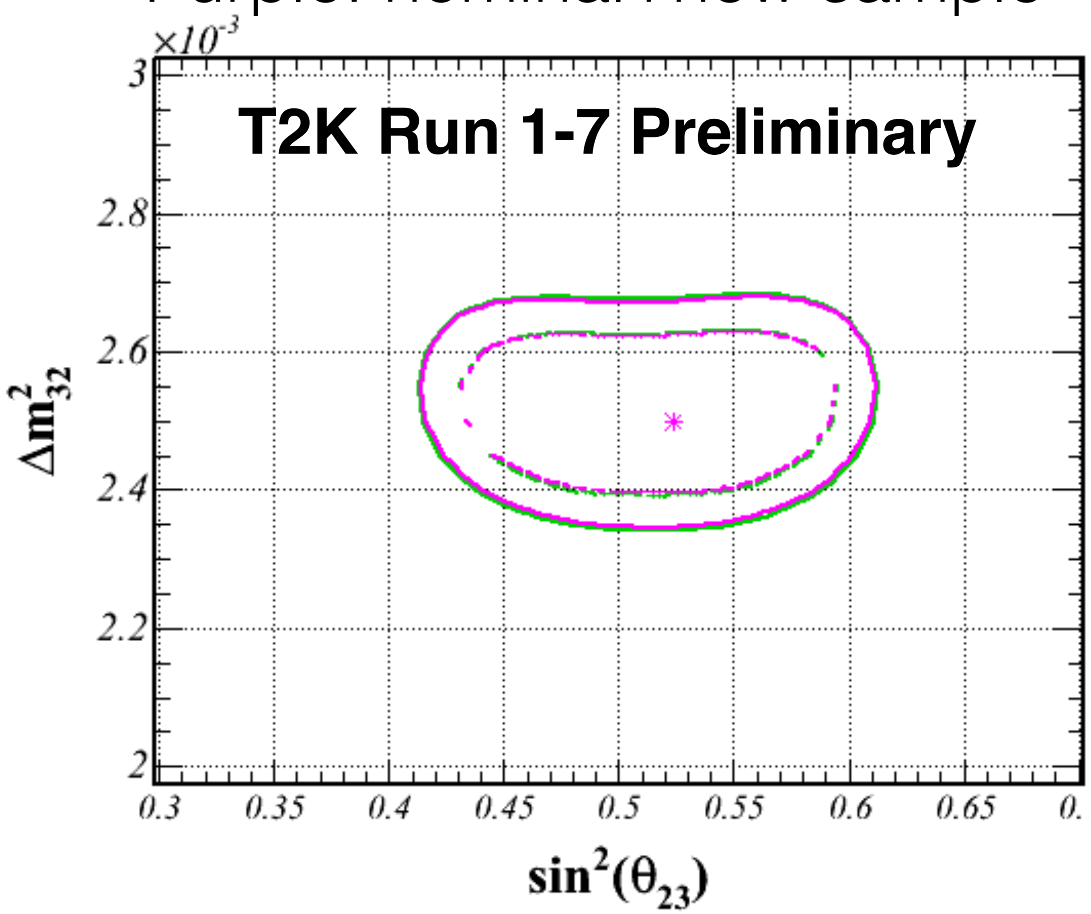


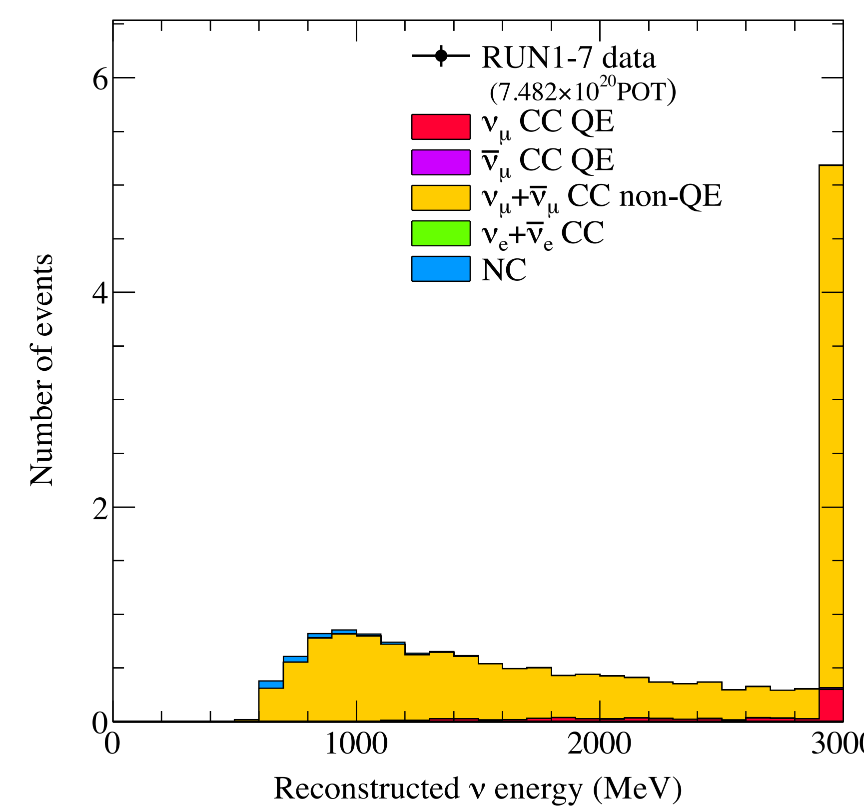
Adding new samples to OA

- Alternative ν_μ selection criteria is applied to study new sample to accompany recent addition of 1Re with 1 decay e (ν_e CC1π^+) sample
- Increased ν-mode ν_μ statistics by ~13.5% (94% purity)



Green: nominal
Purple: nominal+new sample

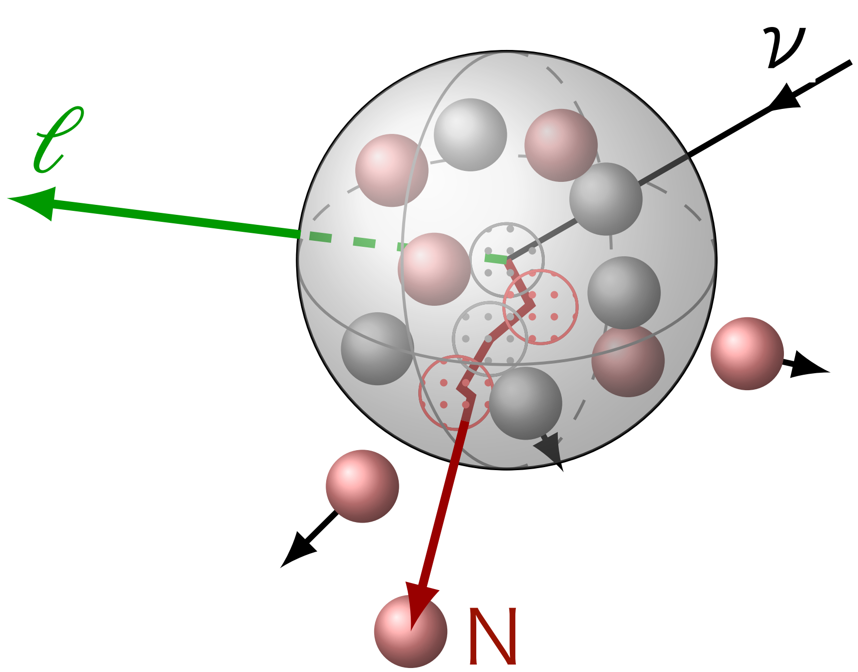


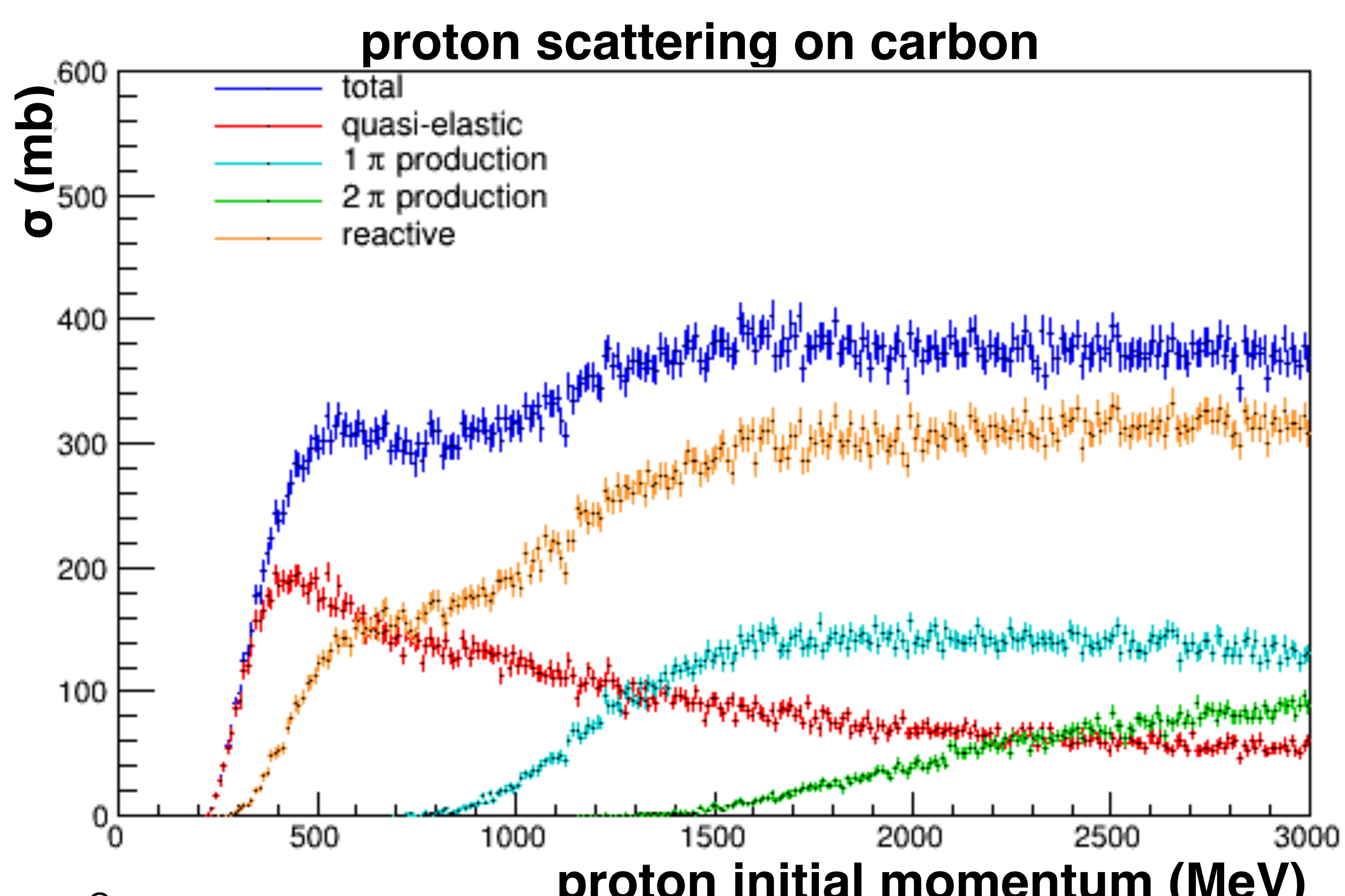


Wing Yan Ma

Proton Final-State Interactions (FSI)

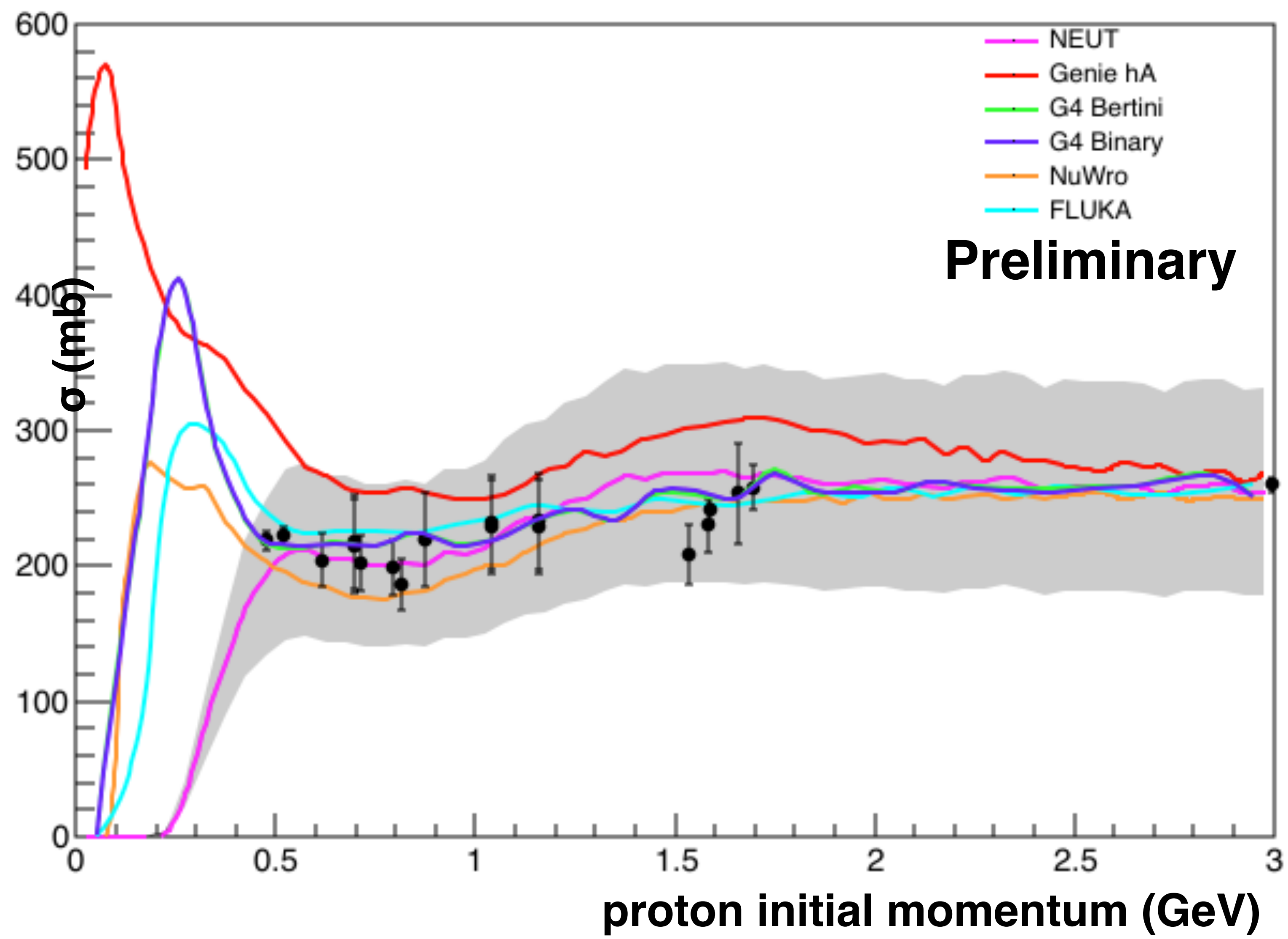
- Important systematic effect as hadrons can re-interact inside nucleus
- I studied the NEUT FSI model and used NEUT to generate MC of proton scattering on fixed target
- I fitted the NEUT cross-section predictions to external data to get averages and uncertainties that can be used by analysers





Tuning FSI parameters

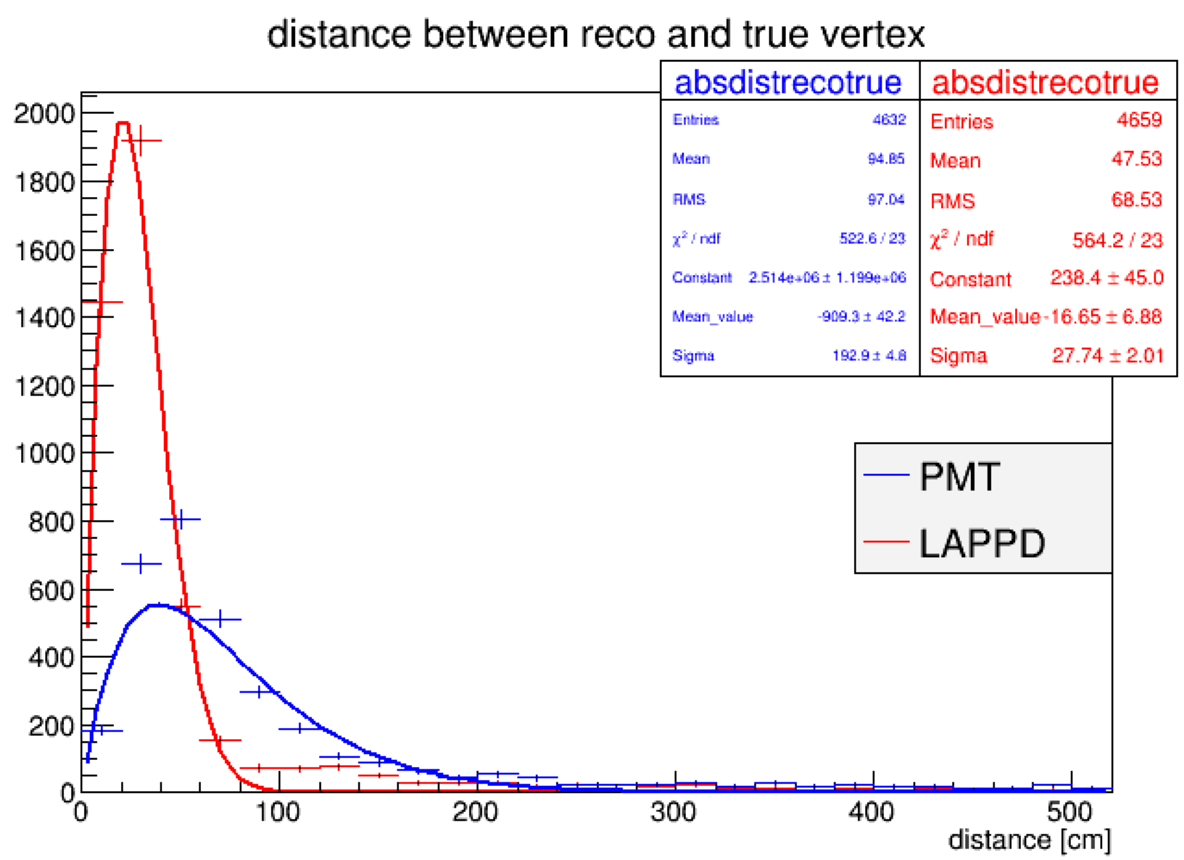
- Tuned free parameters in the NEUT FSI model to fit data and shows agreement other generators
- The tuned results can be propagated to oscillation analyses in the future

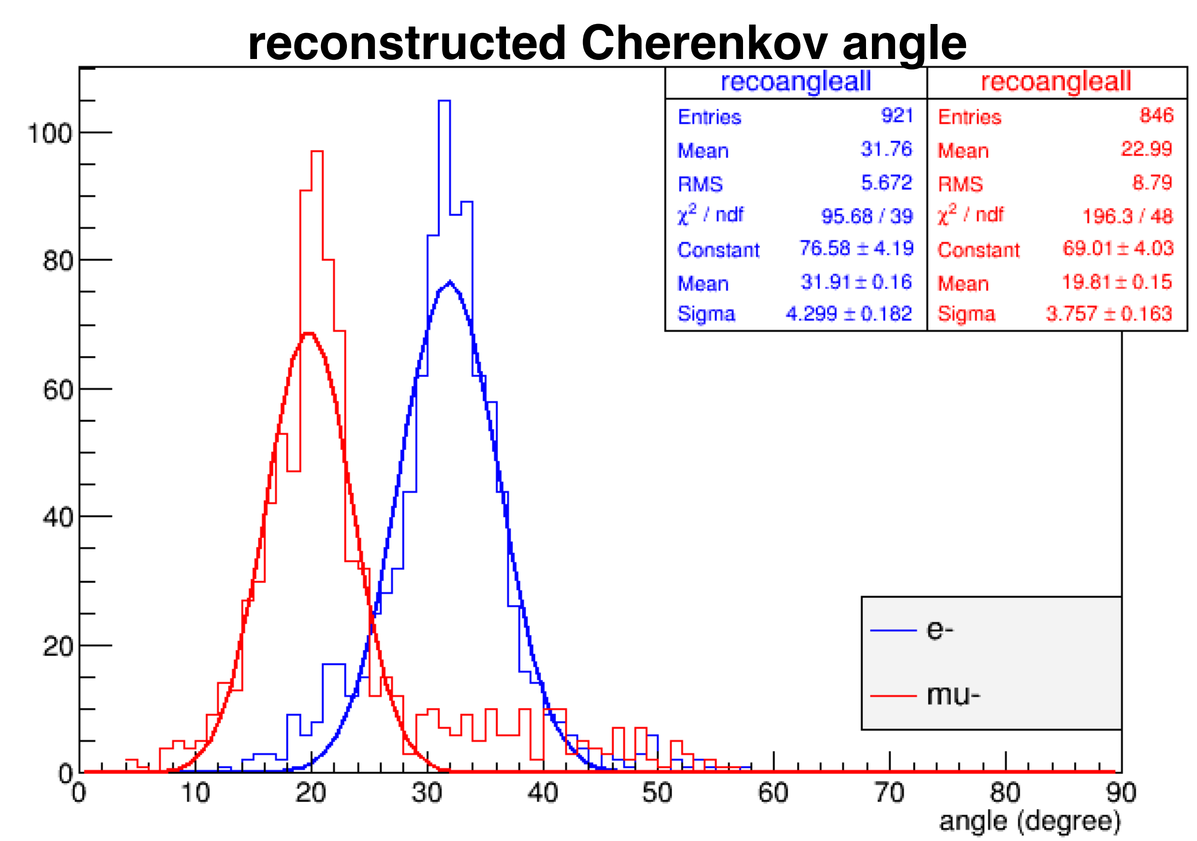


W Y Ma, E S Pinzon Guerra, M Yu, A Fiorentini and T Feusels, "Current status of final- state interaction models and their impact on neutrino-nucleus interactions," Neutrino 2016 conference proceedings

TITUS Low-E reconstruction

- TITUS is a proposed intermediate water Cherenkov detector for Hyper-K (arXiv:1606.08114)
- I developed reconstruction algorithm to perform vertex fitting, energy/Cherenkov angle reconstruction
- Detector optimisation by testing different detector configurations
- Used π^0 particle gun with full reconstruction chain to check ability to reconstruct π^0 s
- Purity of 82% (All NC) and 65% (NCπ^0 only)



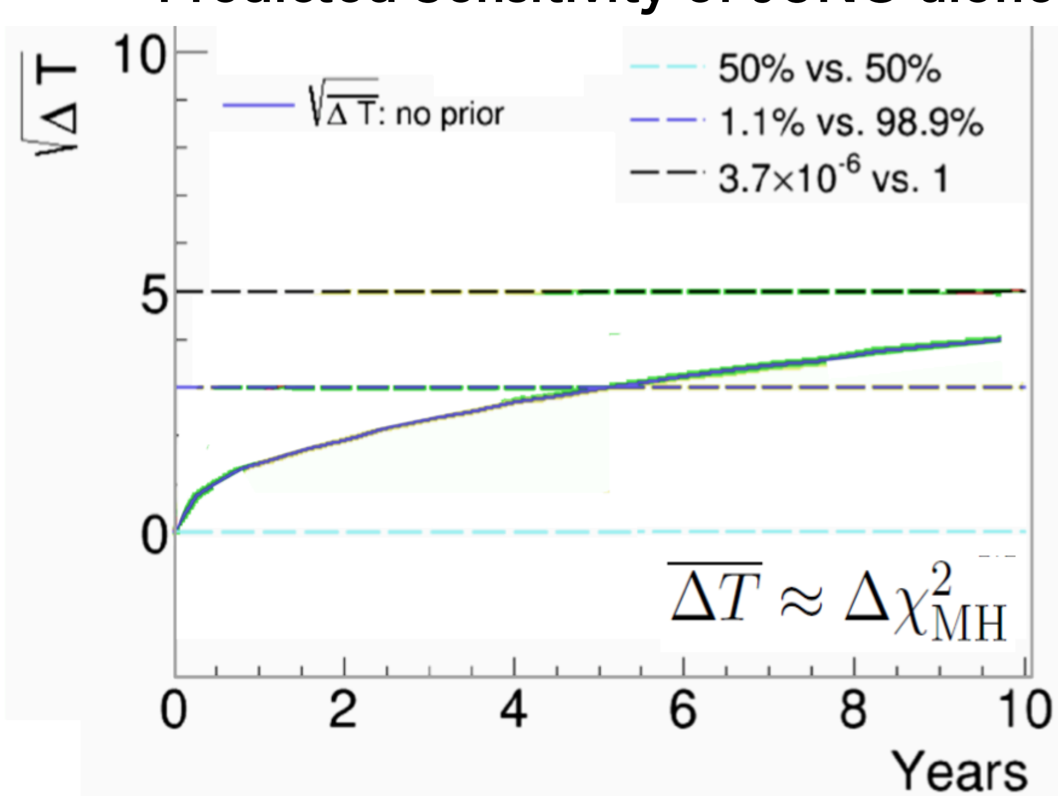


Future work

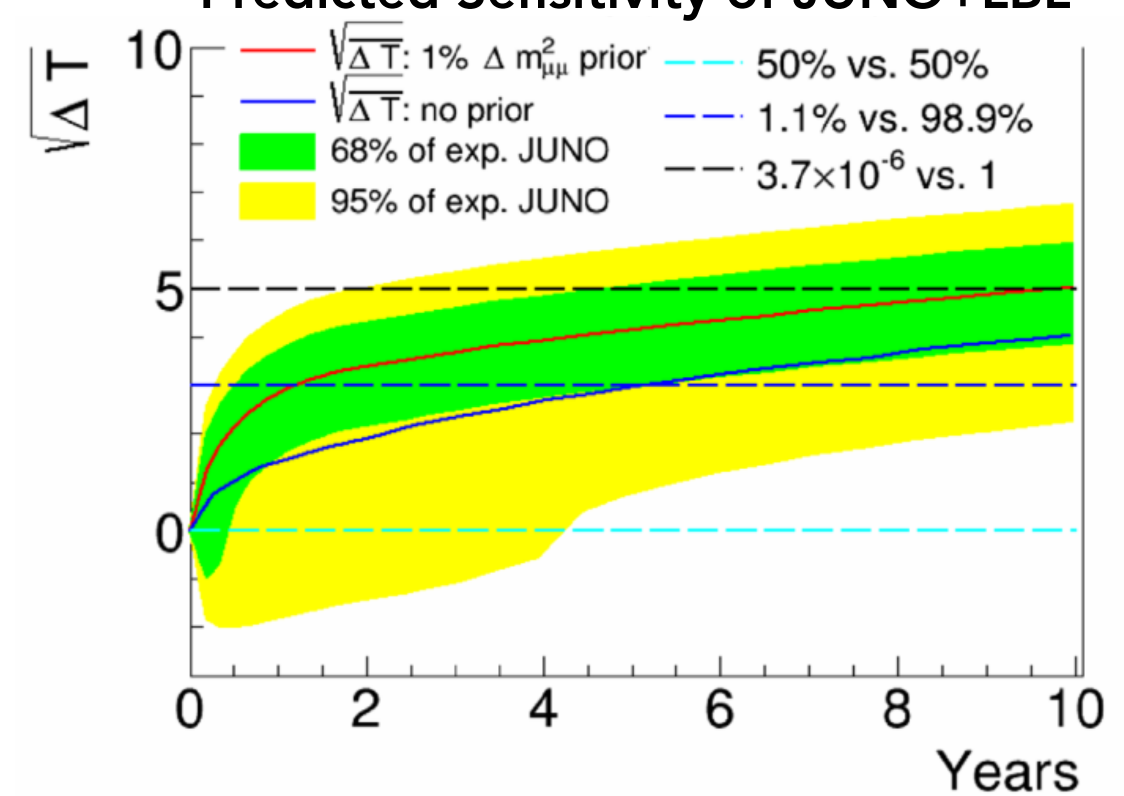
Determine MH using JUNO

- **m_3** state is heaviest (normal hierarchy, NH) or lightest (inverted hierarchy, IH) still unknown
- Together with ongoing efforts of LBL experiments (Δm^2_{32} known better than 1% in the future), can determine MH with higher significance
- 3σ→4σ with 6 years of running assuming required energy resolution etc.
- I plan to study how to combine the data with JUNO, and predict the sensitivity of MH determination

Predicted Sensitivity of JUNO alone



Predicted Sensitivity of JUNO+LBL



Thank you for listening!

Backup

Maximal disappearance

- All results now consistent with T2K
- NOvA: rejection of maximal mixing has changed from 2.6σ to 0.8σ