H. A. TANAKA (UNIVERSITY OF TORONTO/IPP/TRIUMF)
ON BEHALF OF THE T2K COLLABORATION

T2K: LATEST RESULTS

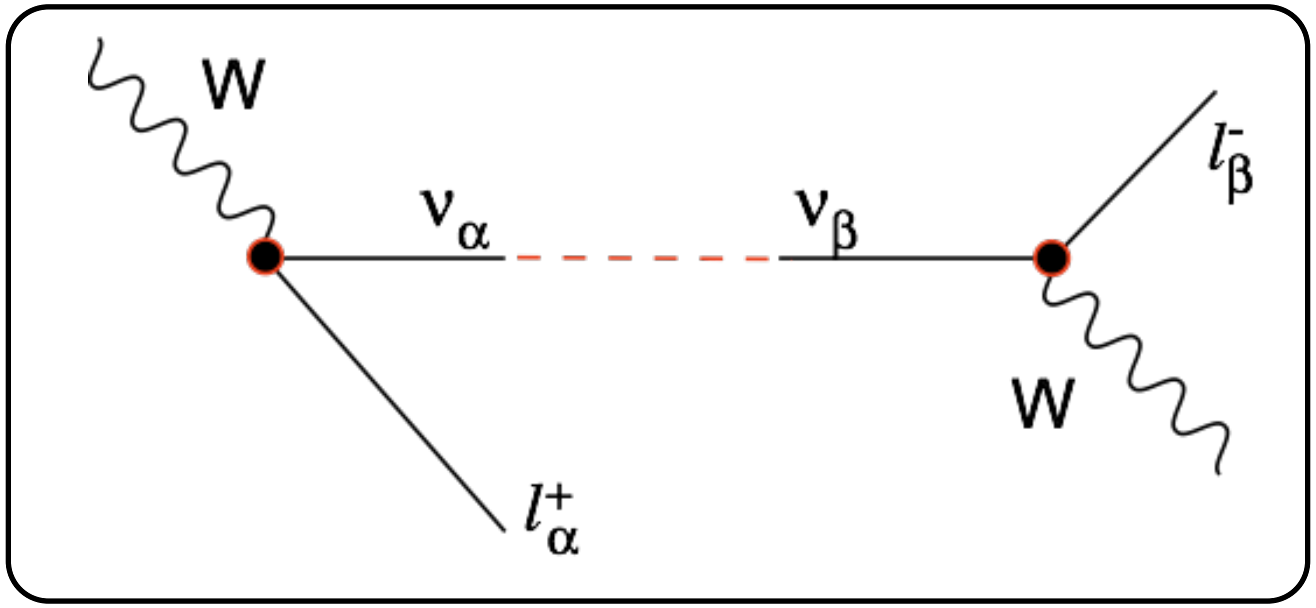
NEUTRINO 2016
SOUTH KENSINGTON, LONDON

XXVII INTERNATIONAL CONFERENCE ON NEUTRINO PHYSICS AND ASTROPHYSICS
4–9 JULY 2016

NEUTRINO OSCILLATIONS

- Neutrinos produced in weak decays are linear combinations of mass/energy eigenstates

$$|\nu_\alpha\rangle = \sum_i U^*_{\alpha i}|\nu_i\rangle$$



- Time evolution: flavour content "oscillates" in L(distance)/E(neutrino)

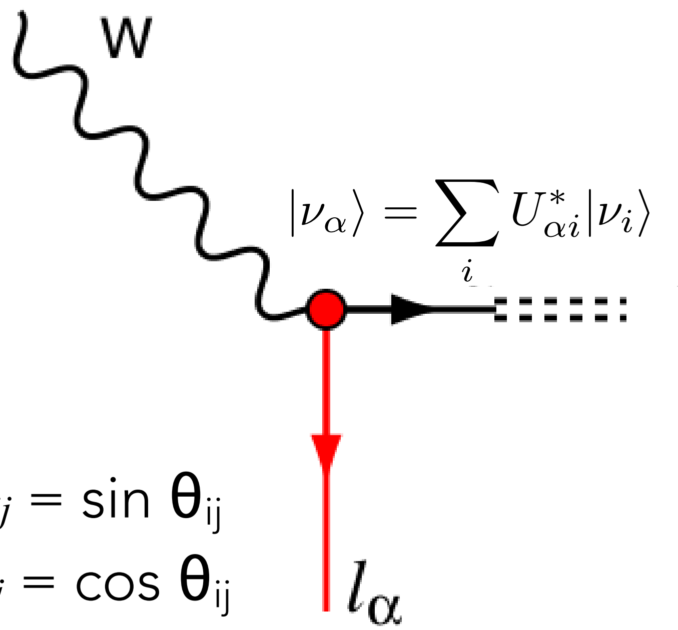
in vacuo

$$\begin{aligned} P(\nu_\alpha \to \nu_\beta) = \quad & \delta_{\alpha\beta} \\ & -4\Sigma_{i>j}\Re(U^*_{\alpha i}U_{\beta i}U_{\alpha j}U^*_{\beta j})\sin^2[1.27\Delta m^2_{ij}(L/E)] \\ & +2\Sigma_{i>j}\Im(U^*_{\alpha i}U_{\beta i}U_{\alpha j}U^*_{\beta j})\sin\ [2.54\Delta m^2_{ij}(L/E)] \end{aligned}$$

- **Amplitudes determined by mixing matrix U_{ij}**
- **Wavelengths determined by mass² differences Δm^2_{ij}**

additional effects in the presence of matter

MIXING OF THREE NEUTRINOS



$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = \begin{pmatrix} U^*_{e1} & U^*_{e2} & U^*_{e3} \\ U^*_{\mu 1} & U^*_{\mu 2} & U^*_{\mu 3} \\ U^*_{\tau 1} & U^*_{\tau 2} & U^*_{\tau 3} \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

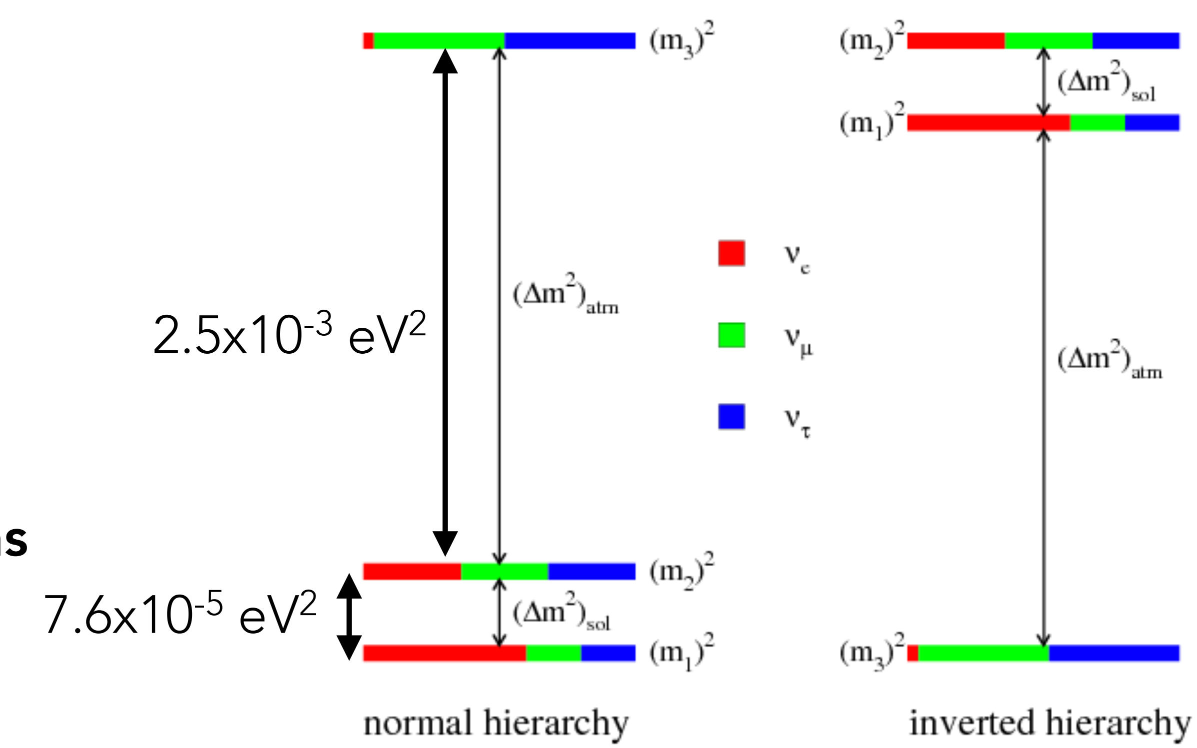
$s_{ij} = \sin \theta_{ij}$

$c_{ij} = \cos \theta_{ij}$

"standard" parametrization

$$U = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix} \begin{pmatrix} c_{13} & 0 & s_{13}e^{-i\delta} \\ 0 & 1 & 0 \\ -s_{13}e^{+i\delta} & 0 & c_{13} \end{pmatrix} \begin{pmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 1 & 0 & 0 \\ 0 & e^{i\alpha_1/2} & 0 \\ 0 & 0 & e^{i\alpha_2/2} \end{pmatrix}$$

- Three rotation angles (θ_{12}, θ_{13}, θ_{23})
  - θ_{12}: solar and reactor experiments
  - θ_{13}: reactor and long-baseline experiments
- One complex phase δ_{CP}
  - additional phases if neutrinos are "Majorana"
  - **CP-odd: changes sign for antineutrino oscillations**

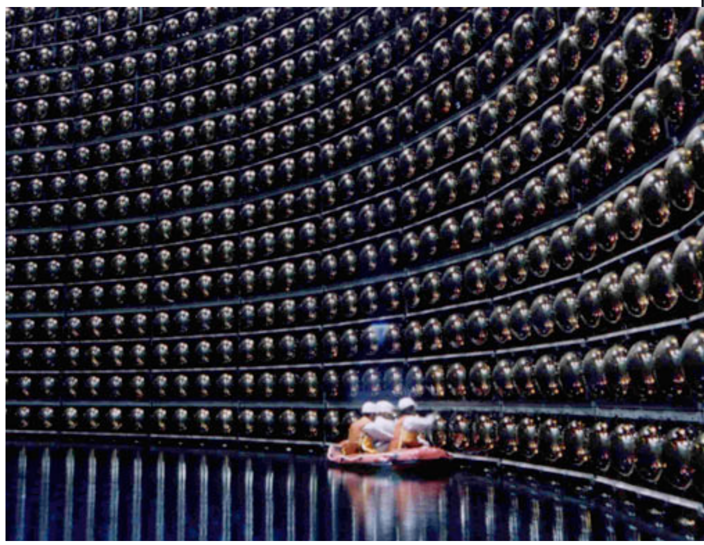


T2K:

ND280
"near" detectors

J-PARC

Super-Kamiokande
"far" detector



~400 collaborators
59 institutions
11 nations

- Intense muon (anti)neutrino beam from J-PARC to Super-K to study:
  - muon (anti) neutrino disappearance ($\nu_\mu \nrightarrow \nu_\mu$, $\overline{\nu}_\mu \nrightarrow \overline{\nu}_\mu$)
  - electron (anti)neutrino appearance ($\nu_\mu \rightarrow \nu_e$, $\overline{\nu}_\mu \rightarrow \overline{\nu}_e$)
  - rich program of
    - neutrino-nucleus interaction studies with near detectors
    - "exotic" physics: Lorentz violation, sterile neutrinos, heavy leptons, etc.
    - Will not be able to discuss these other interesting topics.

POSTERS

T. HAYASHINO	Anti-neutrino beam direction and intensity measurement	P1.036 MON.
A. KNOX	Estimating the pion and kaon contributions to the T2K neutrino beam	P1.037 MON.
M. POSIADALA	Recent T2K flux predictions with NA61/SHINE thin graphite target measurements	P1.038 MON.
C. RICCIO	Muon neutrino and antineutrino selection in the tracker of ND280	P1.039 MON.
A. MISSERT	Improving T2K oscillation analyses using fiTQun	P1.040 MON.
R. SHAH	Muon antineutrino disappearance and electron antineutrino appearance searches	P1.041 MON.
D. SHAW	A CCPi0 inclusive analysis at the T2K near detector	P1.042 MON.
L. ZAMBELLI	Towards T2K neutrino flux predictions using replica target measurements by NA61/SHINE	P1.043 MON.
B. QUILAIN	The WAGASCI detector as an off-axis near detector of the T2K and HK experiments	P3.025 WED.
L. KOCH	Measurement of neutrino interactions in gaseous argon with T2K	P3.029 WED.
P. LASORAK	A search for neutral-current single photons with the ND280 at T2K	P3.031 WED.
W. MA	Current status of final state interactions models . . .	P3.032 WED.
P. MARTINS	Charged-current coherent pion production on oxygen nuclei in the T2K near detector	P3.033 WED.
J. ZALIPSKA	Reconstruction of low momentum protons with FGD of the T2K experiment	P3.034 WED.
D. COPLOWE	Resonance production cross-section measurement in neutrino-H interactions . .	P3.035 WED.
S. BORDONI	CCmuon neutrino shape and rate analysis at the T2K off-axis near detector	P3.074 WED.
T. VLADISAVLJEVIC	Probing Nuclear Effects at the T2K Near Detector Using Transverse Kinematic Variables	P3.097 WED.
A. IZMAYLOV	Search for heavy neutral leptons with the near detector complex . . .	P4.014 FRI.
M. FRIEND	Physics sensitivity of a possible extended T2K Run -- T2K phase 2	P4.022 FRI.
K. DUFFY	First joint analysis of neutrino and antineutrino oscillation at T2K	P4.023 FRI.
J. LAGODA	Probing K-originated neutrinos with the muons produced outside of ND280	P4.024 FRI.
G. CHRISTODOULOU	Measurement of electron (anti-)neutrinos at the T2K near detector	P4.025 FRI.
C. WRET	Single-pion production in the NEUT neutrino interaction generator	P4.029 FRI.

more details and topics! Please see!

ν OSCILLATIONS AT T2K

$$P(\nu_\mu \to \nu_\mu) \sim 1 - \left(\cos^4\theta_{13}\sin^2 2\theta_{23} + \sin^2 2\theta_{13}\sin^2\theta_{23}\right)\sin^2\Delta m^2_{31}\frac{L}{4E}$$

- Precision measurement of $2\theta_{23}$ and Δm^2_{31}
- CPT tests with antineutrino mode ($\bar{\nu}_\mu \to \bar{\nu}_\mu$)

$$\begin{aligned} P(\nu_\mu \to \nu_e) \sim\ & \sin^2 2\theta_{13} \times \sin^2\theta_{23} \times \frac{\sin^2[(1-x)\Delta]}{(1-x)^2} \\ & -\alpha\sin\delta \times \sin 2\theta_{12}\sin 2\theta_{13}\sin 2\theta_{23} \times \sin\Delta\,\frac{\sin[x\Delta]}{x}\,\frac{\sin[(1-x)\Delta]}{(1-x)} \\ & +\alpha\cos\delta \times \sin 2\theta_{12}\sin 2\theta_{13}\sin 2\theta_{23} \times \cos\Delta\,\frac{\sin[x\Delta]}{x}\,\frac{\sin[(1-x)\Delta]}{(1-x)} \\ & +\mathcal{O}(\alpha^2) \end{aligned}$$

$$\alpha = \left|\frac{\Delta m^2_{21}}{\Delta m^2_{31}}\right| \sim \frac{1}{30} \qquad \Delta \equiv \frac{\Delta m^2_{31}L}{4E} \qquad x \equiv \frac{2\sqrt{2}G_F N_e E}{\Delta m^2_{31}}$$

M. Freund, Phys.Rev. D64 (2001) 053003

- $\sin^2 2\theta_{13}$ dependence of leading term
- θ_{23} dependence of leading term: "octant" dependence (θ_{23}=/>/<45°?)
- CP odd phase δ: asymmetry of probabilities $P(\nu_\mu \to \nu_e) \neq P(\bar{\nu}_\mu \to \bar{\nu}_e)$ if sin δ ≠ 0
- Matter effect through x: ν_e ($\bar{\nu}_e$) enhanced in normal (inverted) hierarchy

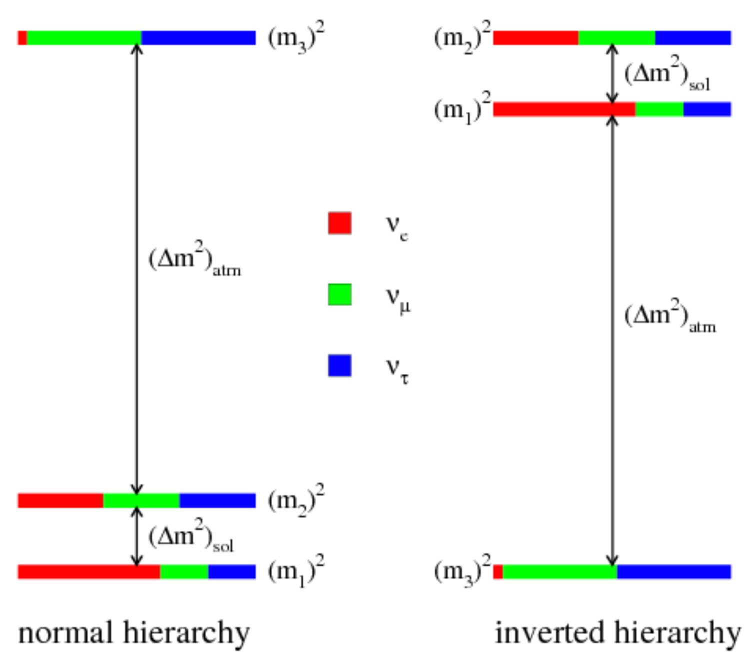
QUICK SUMMARY

- **$\sin^2\theta_{23}$, $\sin^2 2\theta_{13}$**
  - enhance/suppress both $\nu_\mu \to \nu_e$ and $\bar{\nu}_\mu \to \bar{\nu}_e$
- **CP violating parameter δ_{CP}** *up to ±30% effect at T2K*
  - $\delta_{CP}=0,\pi$: no CP violation: vacuum oscillation probabilities equal
  - $\delta_{CP} \sim -\pi/2$: enhance $\nu_\mu \to \nu_e$, suppress $\bar{\nu}_\mu \to \bar{\nu}_e$
  - $\delta_{CP} \sim +\pi/2$: suppress $\nu_\mu \to \nu_e$, enhance $\bar{\nu}_\mu \to \bar{\nu}_e$

"normal" hierarchy (NH):

- enhance $\nu_\mu \to \nu_e$
- suppresses $\bar{\nu}_\mu \to \bar{\nu}_e$

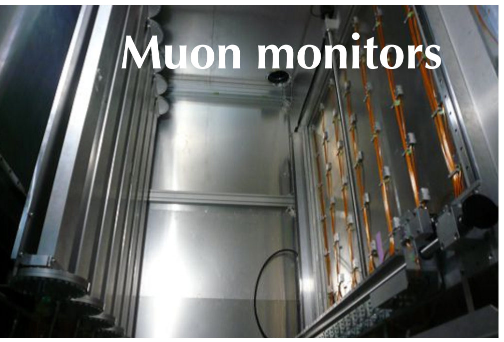
±10% effect at T2K

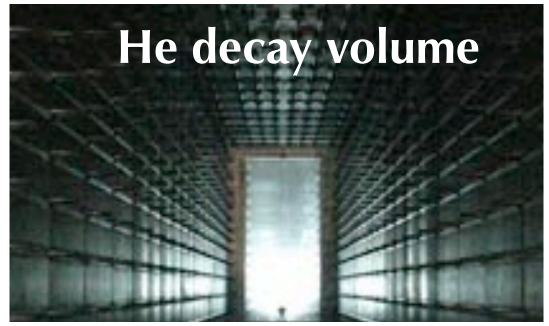


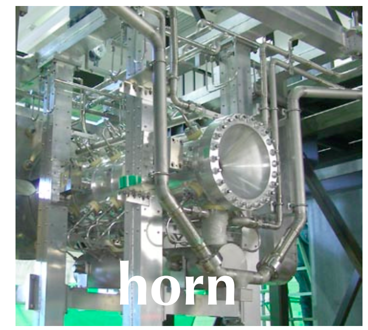
"inverted" hierarchy: (IH)

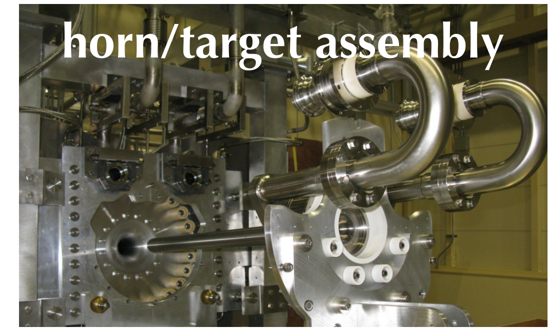
- suppress $\nu_\mu \to \nu_e$
- enhance $\bar{\nu}_\mu \to \bar{\nu}_e$

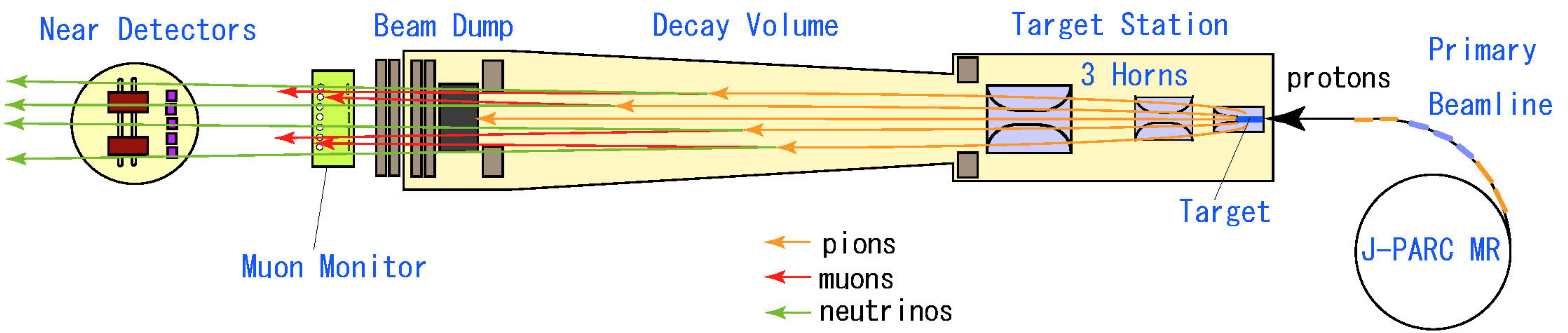
PRODUCING THE BEAM



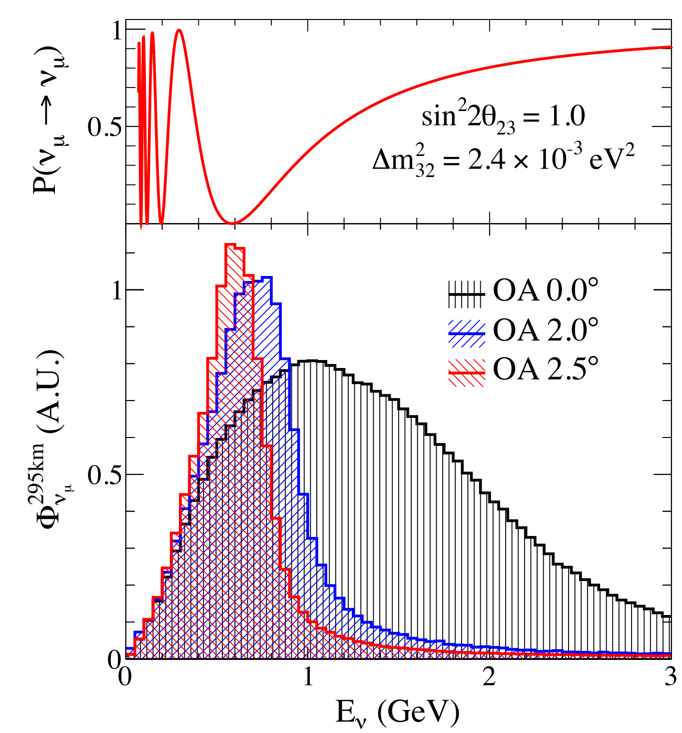




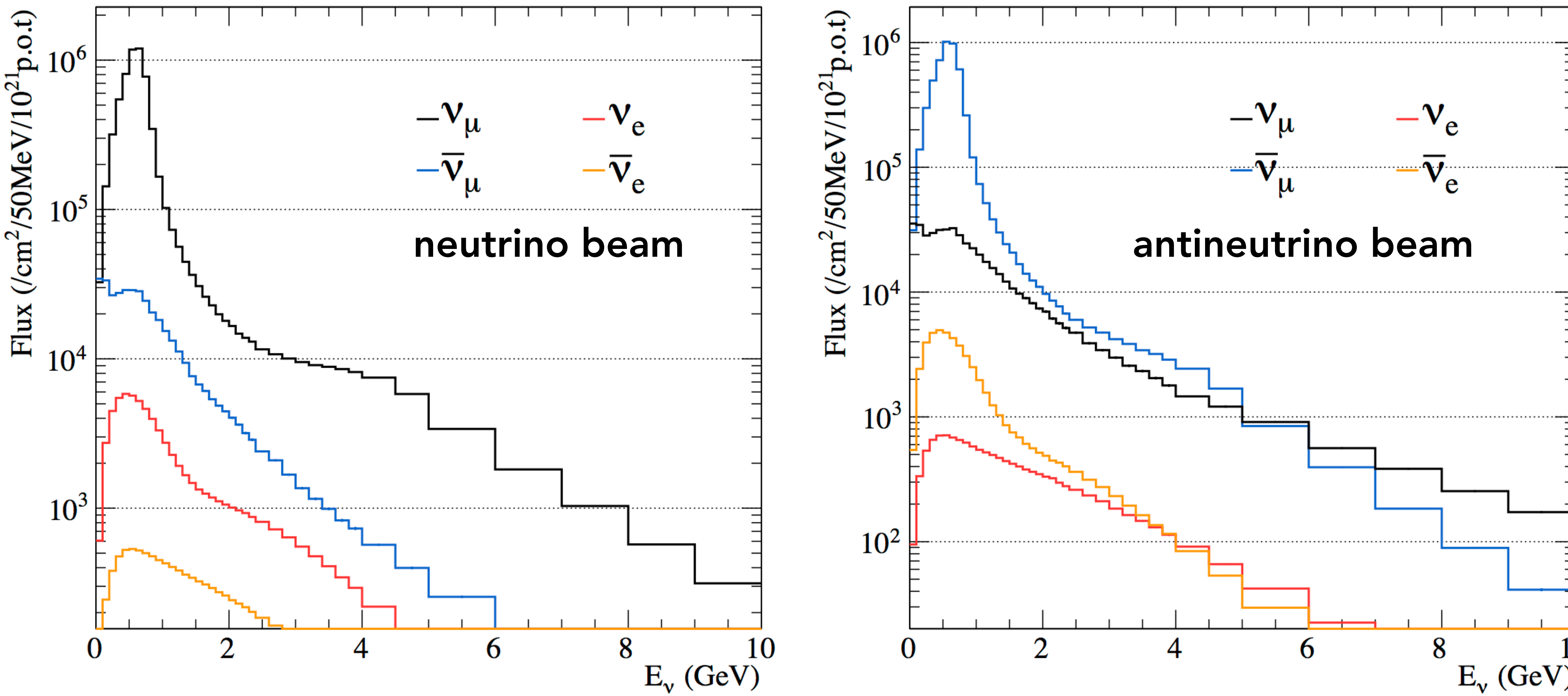




- 30 GeV protons extracted from J-PARC MR to carbon target
  - secondary π^+ focussed by three magnetic "horns"
  - primarily ν_μ beam from $\pi^+ \rightarrow \mu^+ + \nu_\mu$
    - reverse polarity for antineutrino beam: $\pi^- \rightarrow \mu^- + \bar{\nu}_\mu$
  - spectrum peaked at 600 MeV 2.5° "off axis" towards SK
    - expected oscillation "maximum" for L=295 km



NEUTRINO AND ANTINEUTRINO



$$\pi^+ \rightarrow \mu^+ + \nu_\mu \qquad \pi^- \rightarrow \mu^- + \bar{\nu}_\mu$$

- <1% impurity from $\nu_e(\bar{\nu}_e)$ at energy peak; important background for $\nu_e(\bar{\nu}_e)$appearance
- “wrong sign” component: neutrinos contaminating antineutrino beam, vice versa.

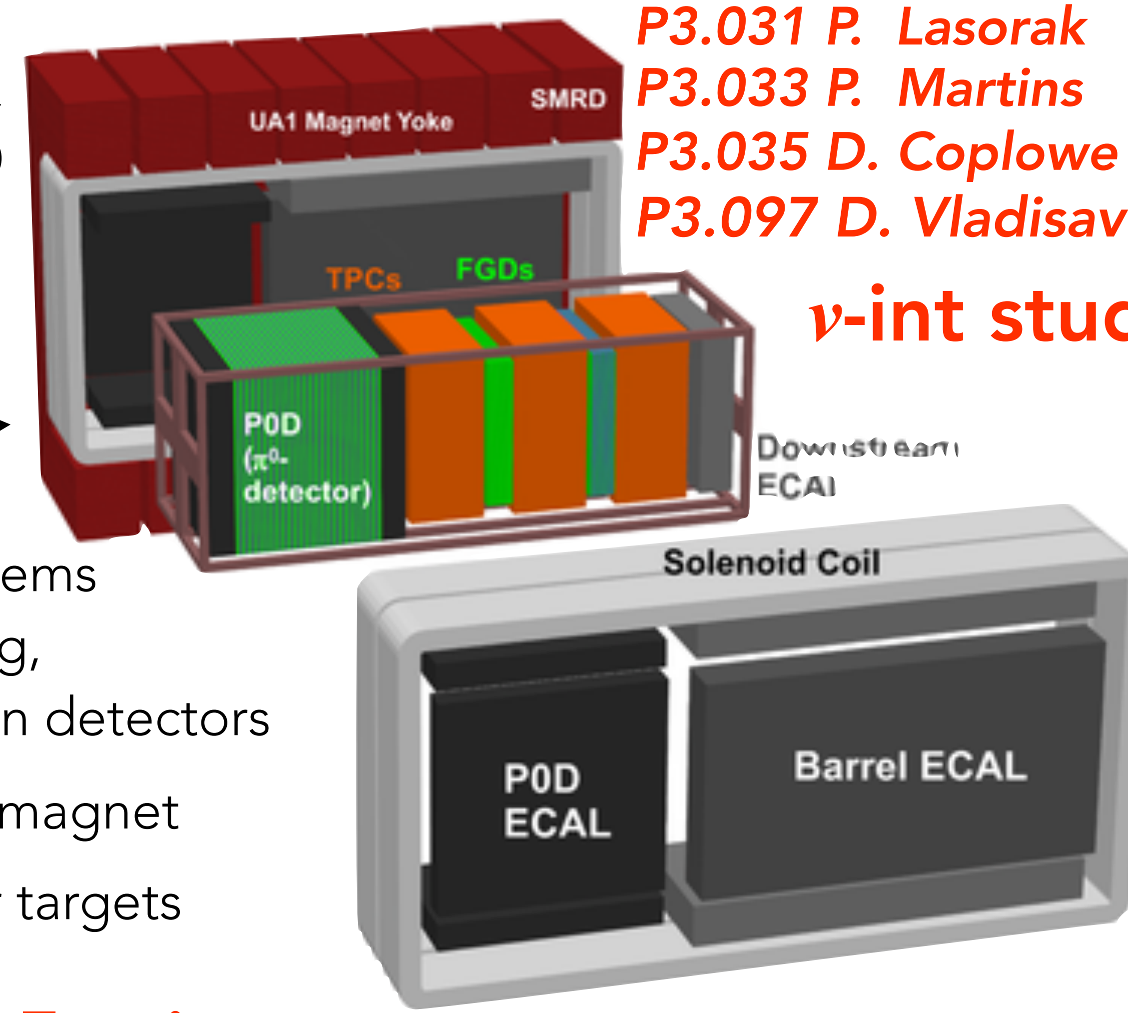
P1.037 A. Knox P4.025 G. Christodoulou

P4.024 J. Łagoda

NEAR DETECTORS

P1.042 D. Shaw
P3.031 P. Lasorak
P3.033 P. Martins
P3.035 D. Coplowe
P3.097 D. Vladisavljevic

ν-int studies

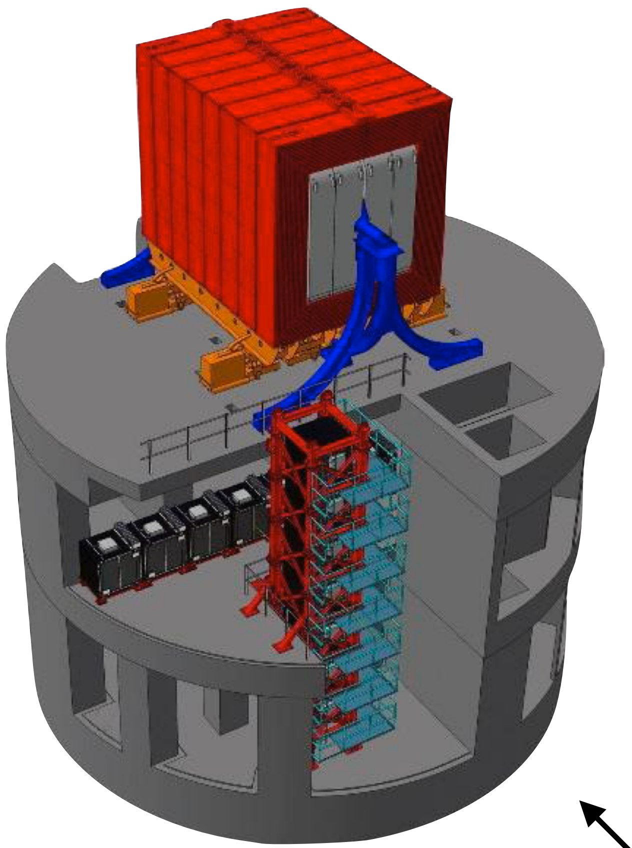


ν

ND280:

- off-axis detector systems comprised of tracking, calorimetry and muon detectors
- 0.2 T field from UA1 magnet
- scintillator and water targets

Exotics *P3.074 S. Bordoni P4.014 A. Izmaylov*

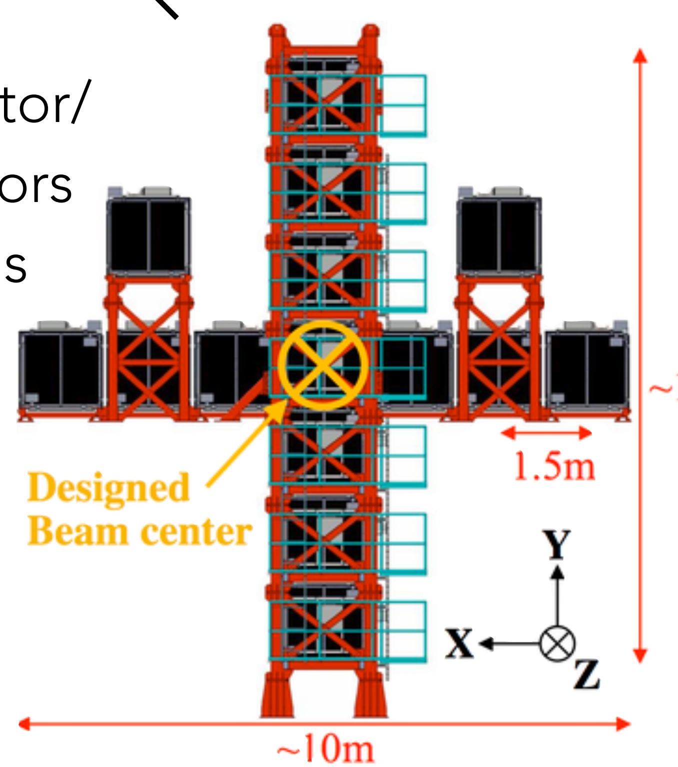


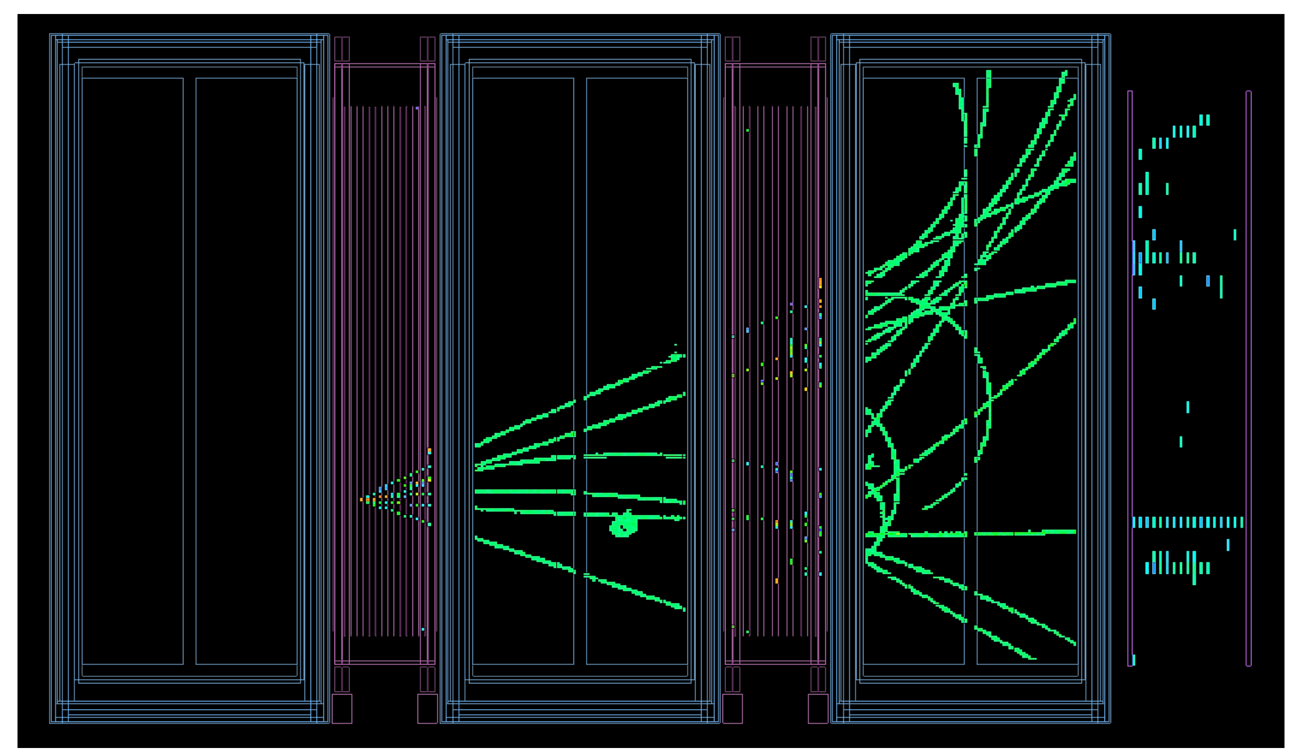
ν

INGRID

- 7x7 grid of scintillator/ Fe neutrino detectors spanning beam axis
- monitor beam direction and rate

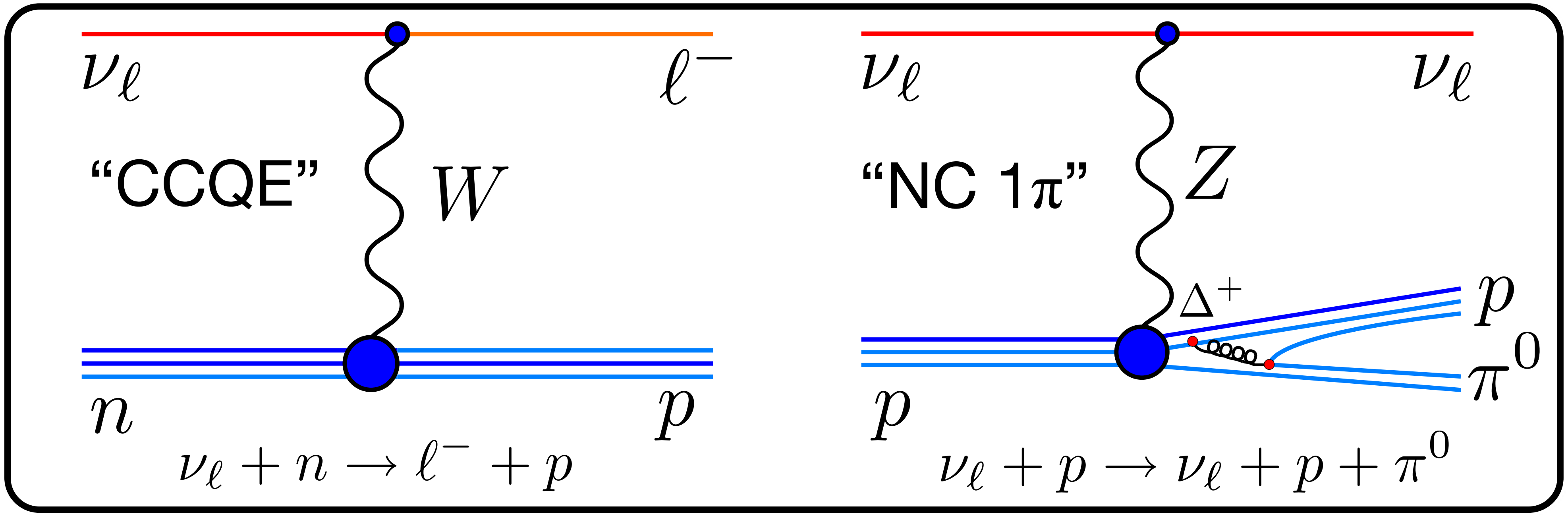
P1.036 T. Hayashino





Reconstruction *P3.029 L. Koch P3.034 J. Zalipska*

NEUTRINOS AT T2K-SK



$\nu_\ell + n \to \ell^- + p \qquad \bar{\nu} + p \to \ell^+ + n$ **Signal**

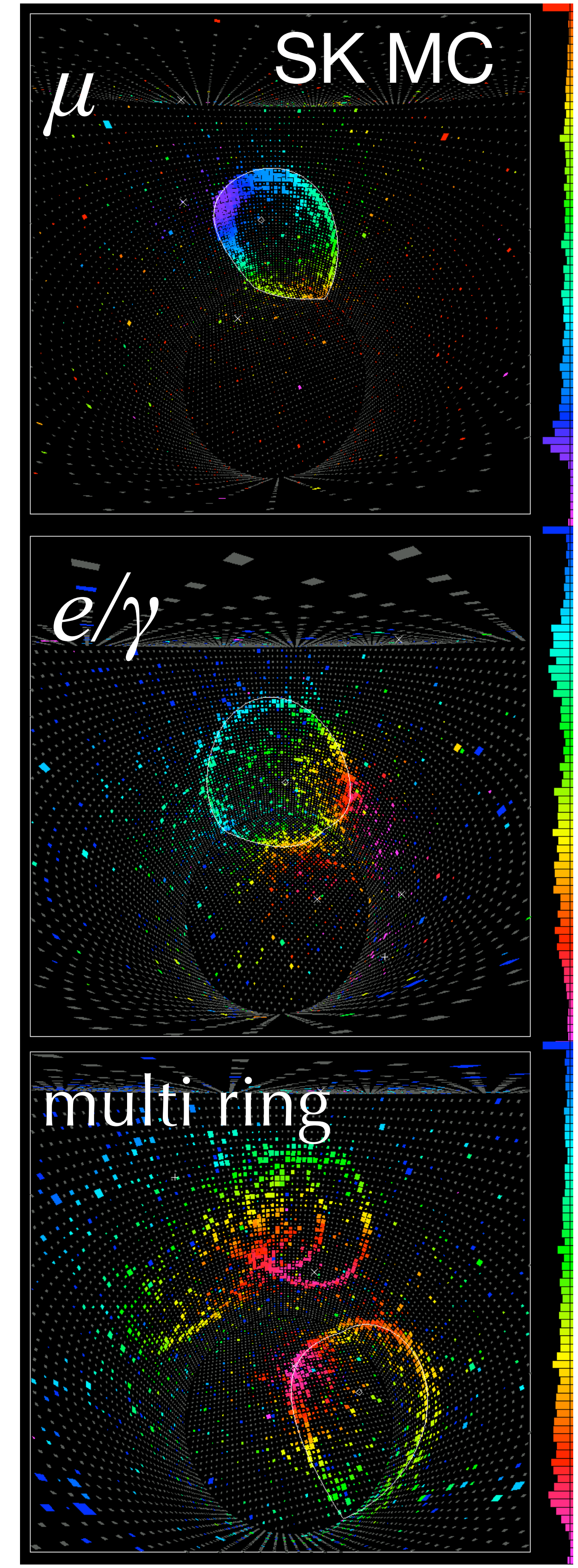
- Single μ/e-like ring
- E_{rec} by energy/direction of lepton, 2-body kinematics

$\nu_\ell + (n/p) \to \nu_\ell + (n/p) + \pi^0$ **Backgrounds**

$\nu_\ell + (n/p) \to \ell^- + (n/p) + \pi$

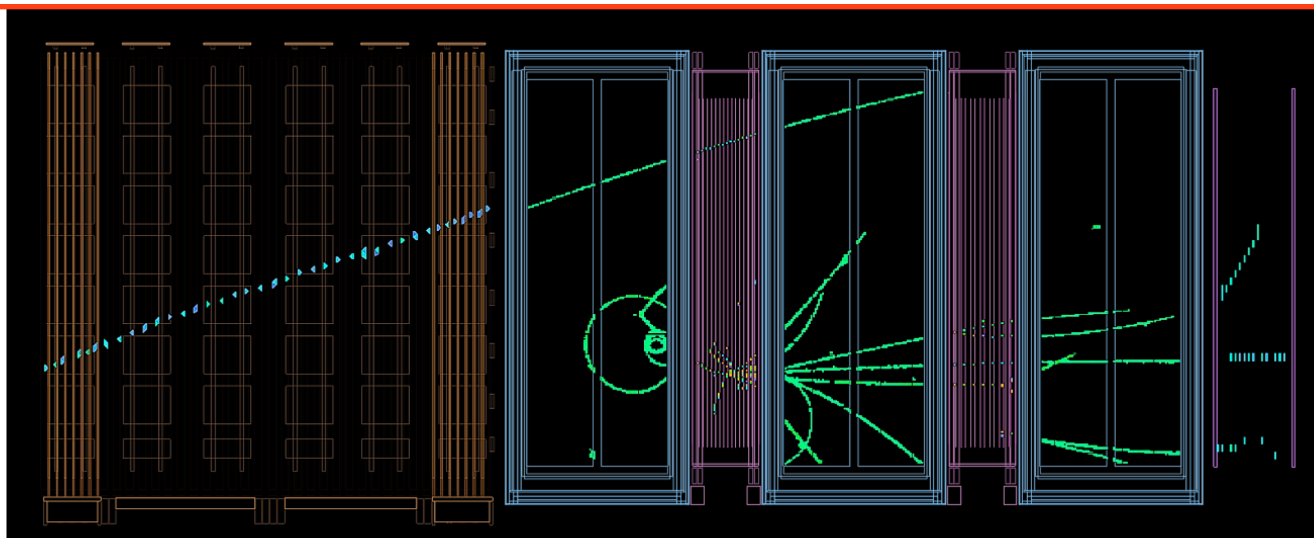
- $\pi^0 \to \gamma + \gamma$: ring counting, 2-ring reconstruction
  - γ misidentified as e from ν_e CCQE
  - powerful rejection capabilities reduce this by $O(10^2)$
- Ring counting, decay electron cut to reject nCCQE

- Pure ν_e samples (S/B~10 at peak) obtained with high efficiency



P1.040 A. Missert

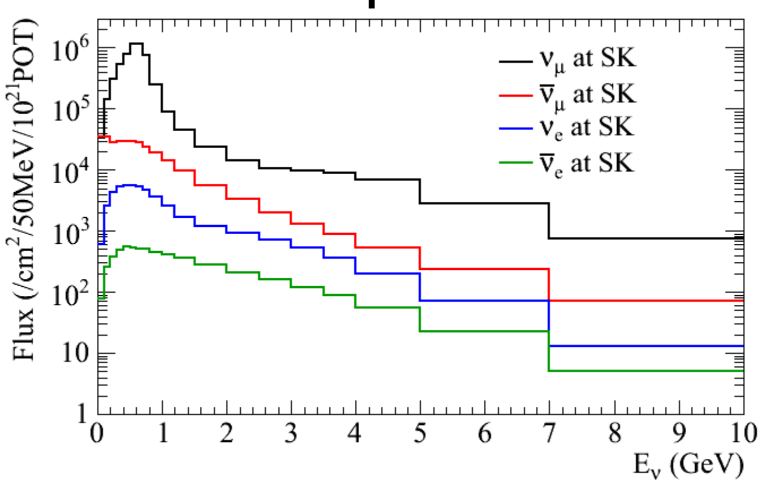
ANALYSIS STRATEGY



Near detectors observe the neutrinos prior to oscillations

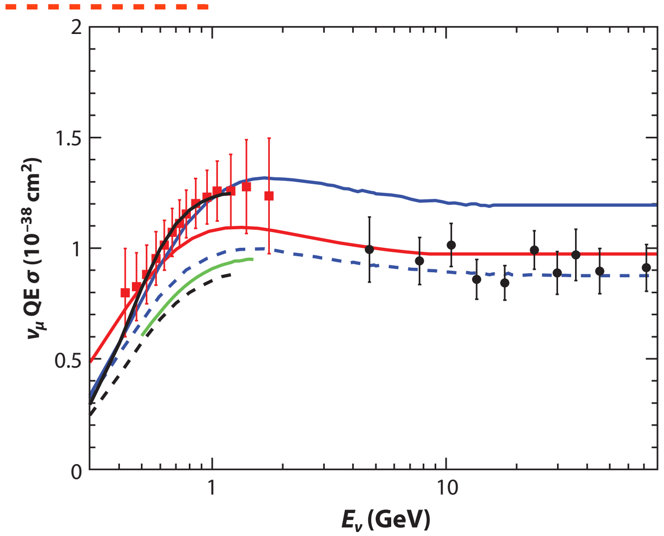
$\varphi_\nu \cdot \sigma_\nu \cdot \varepsilon_{NEAR}$

φ_ν



MC simulation of neutrino beamline tuned with external data (NA61) + beam monitor measurements

σ_ν

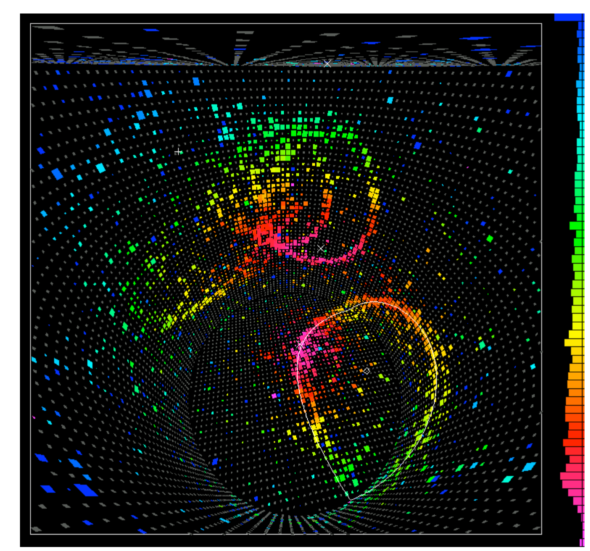


Neutrino cross section and interaction model tuned to external measurements

Far (L=295 km)
$\nu_\mu \rightarrow \nu_e$ (θ_{23}, θ_{13}, δ_{CP})
$\nu_\mu \rightarrow \nu_{\mu/\tau}$ ($2\theta_{23}$, Δm^2_{32})
ν_μ, ν_e backgrounds

$$N = \varphi_\nu \cdot \sigma_\nu \cdot \varepsilon_{FAR} \cdot P_{osc}$$

ε_{FAR}



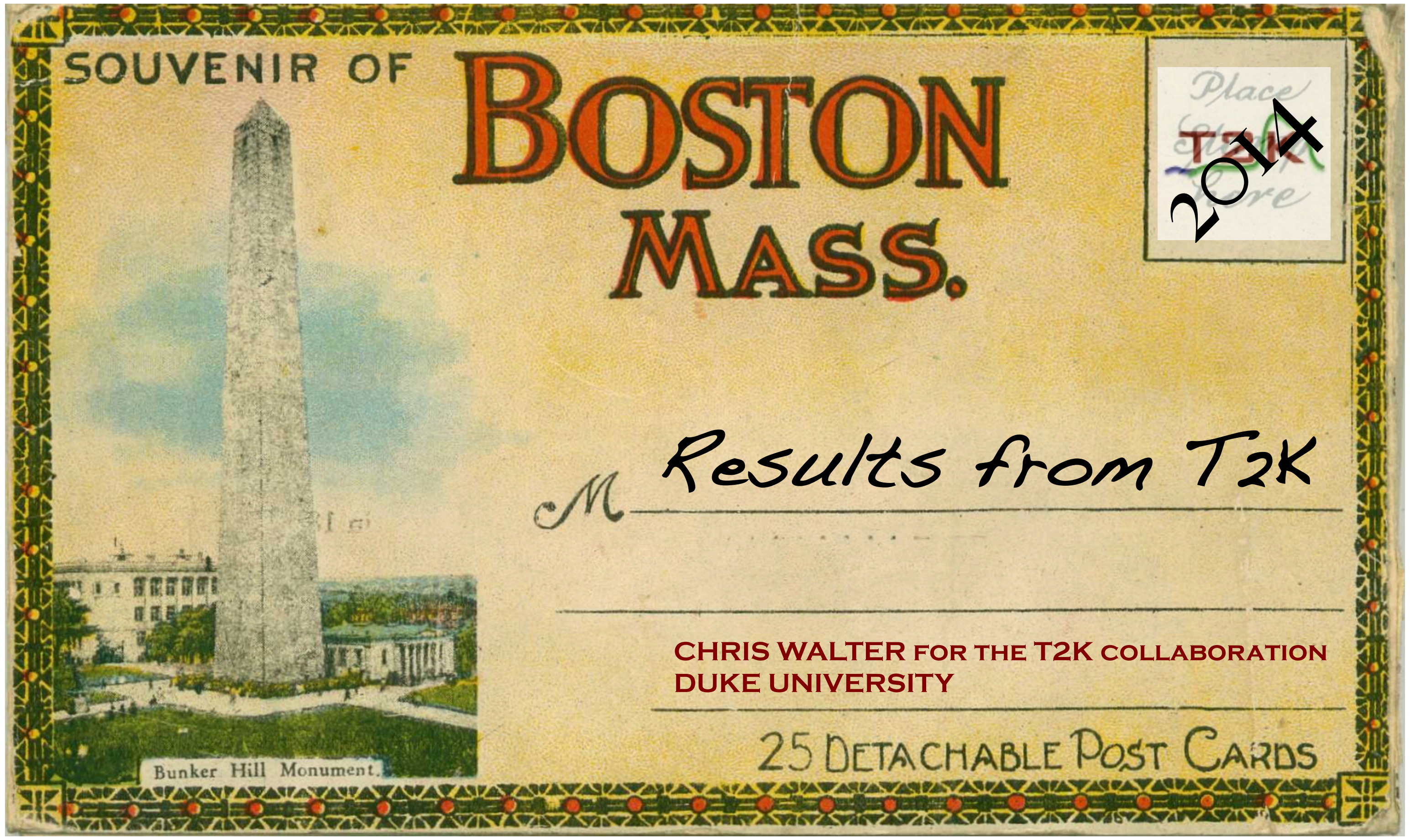
Detector simulation to determine efficiencies/ backgrounds

P1.036 M. Posiadala
P1.043 L. Zambelli

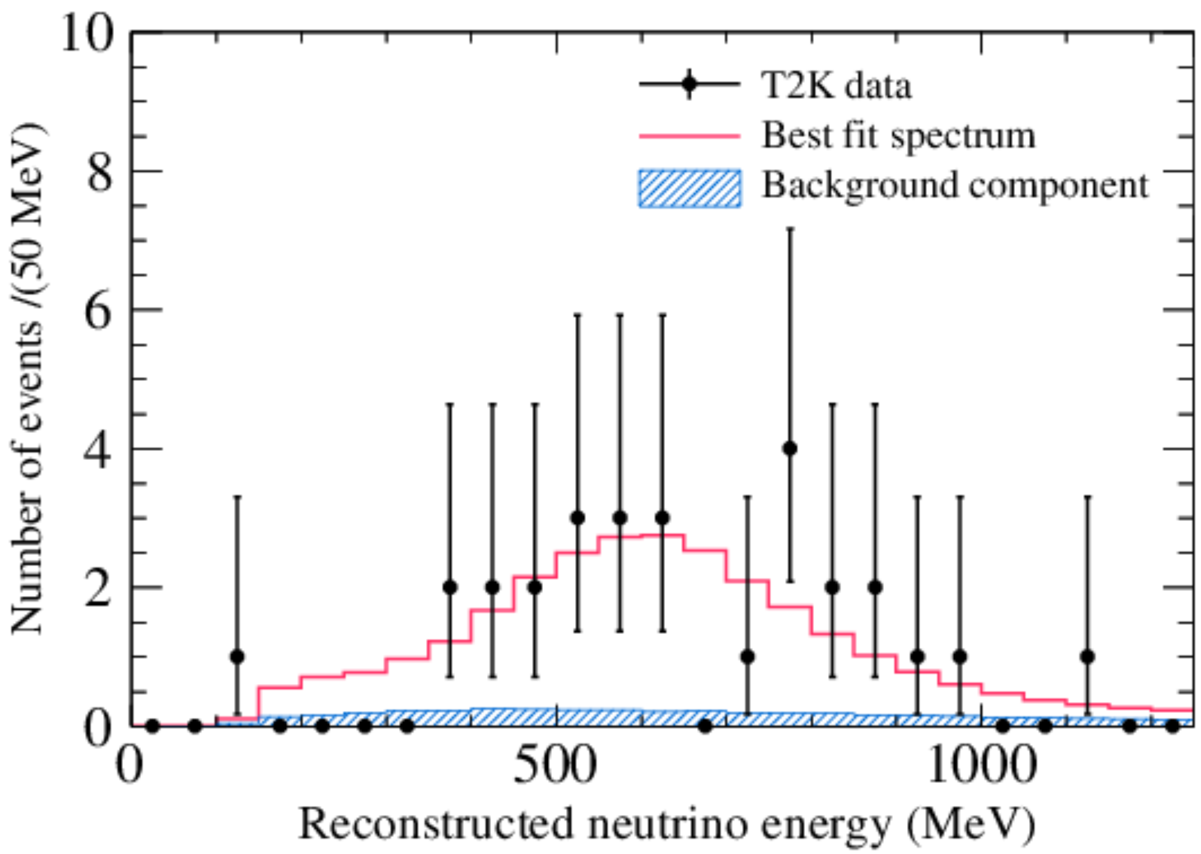
Wed. Talk by L. Zambelli

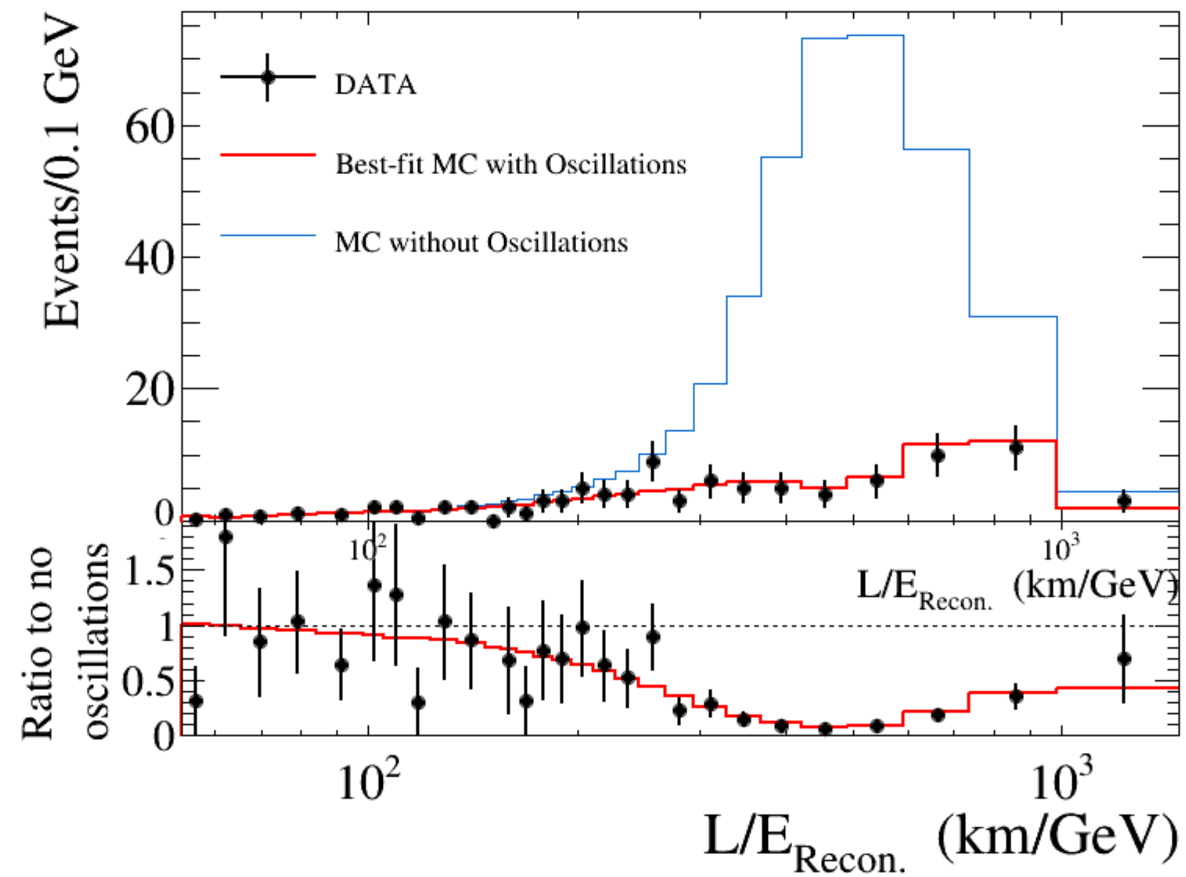
P3.032 W. Ma
P4.029 C. Wret

PREVIOUSLY ON T2K . . . .



NEUTRINO MODE DATA





- 28 ν_e candidates observed
  - 5.0 expected in absence of oscillation effects
  - definitive observation of $\nu_\mu \to \nu_e$ oscillations
- 120 ν_μ candidates observed
  - 446 expected in absence of oscillation effects
  - Most precise determination of ν_μ disappearance

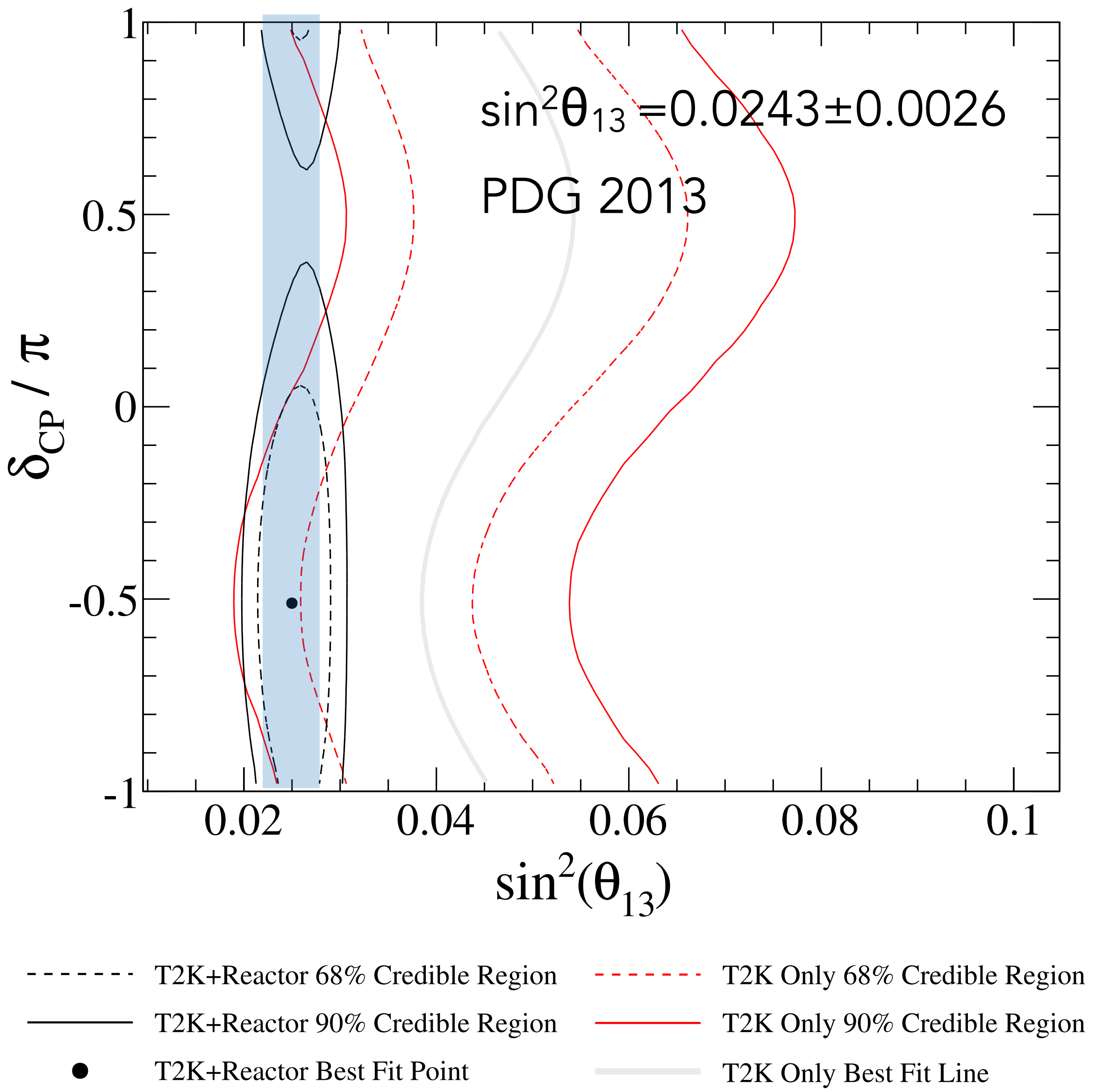
$$\sin^2\theta_{23} = 0.514^{+0.055}_{-0.056}$$

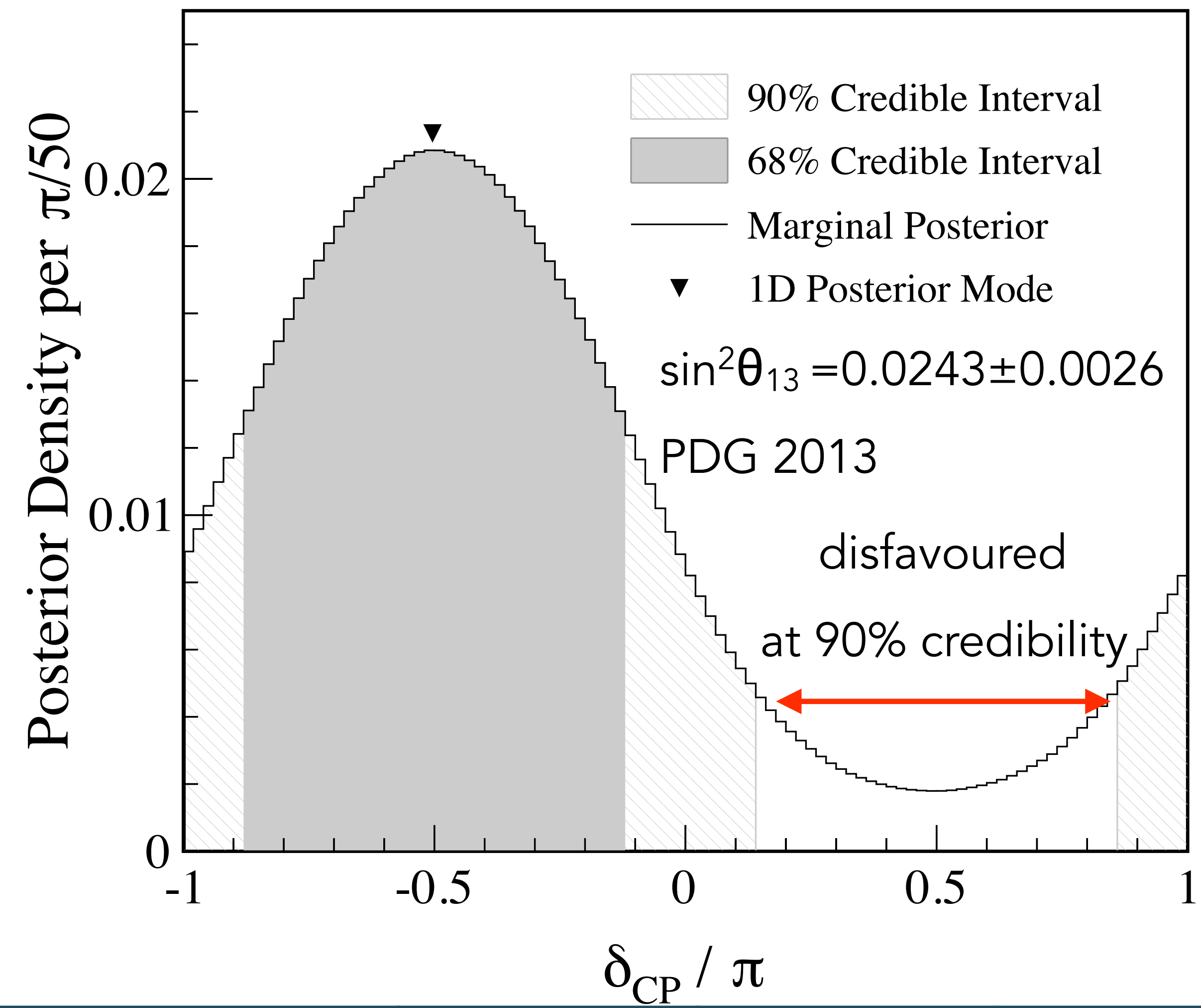
$$|\Delta m^2_{32}| = (2.51 \pm 0.11) \times 10^{-3} \text{eV}^2/c^4$$

	Osc.	No osc.
ν_μ	0.9	1.4
$\bar{\nu}_\mu$	0.1	0.1
$\nu_e/\bar{\nu}_e$	3.3	3.5
$\nu_\mu \to \nu_e$	16.6	0.0
$\bar{\nu}_\mu \to \bar{\nu}_e$	0.2	0.0
Total	21.1	5.0

expected number of ν_e candidates for $\delta_{CP} = 0$, $\sin^2\theta_{23} = 0.5$, NH

JOINT $\nu_\mu + \nu_e$ ANALYSIS





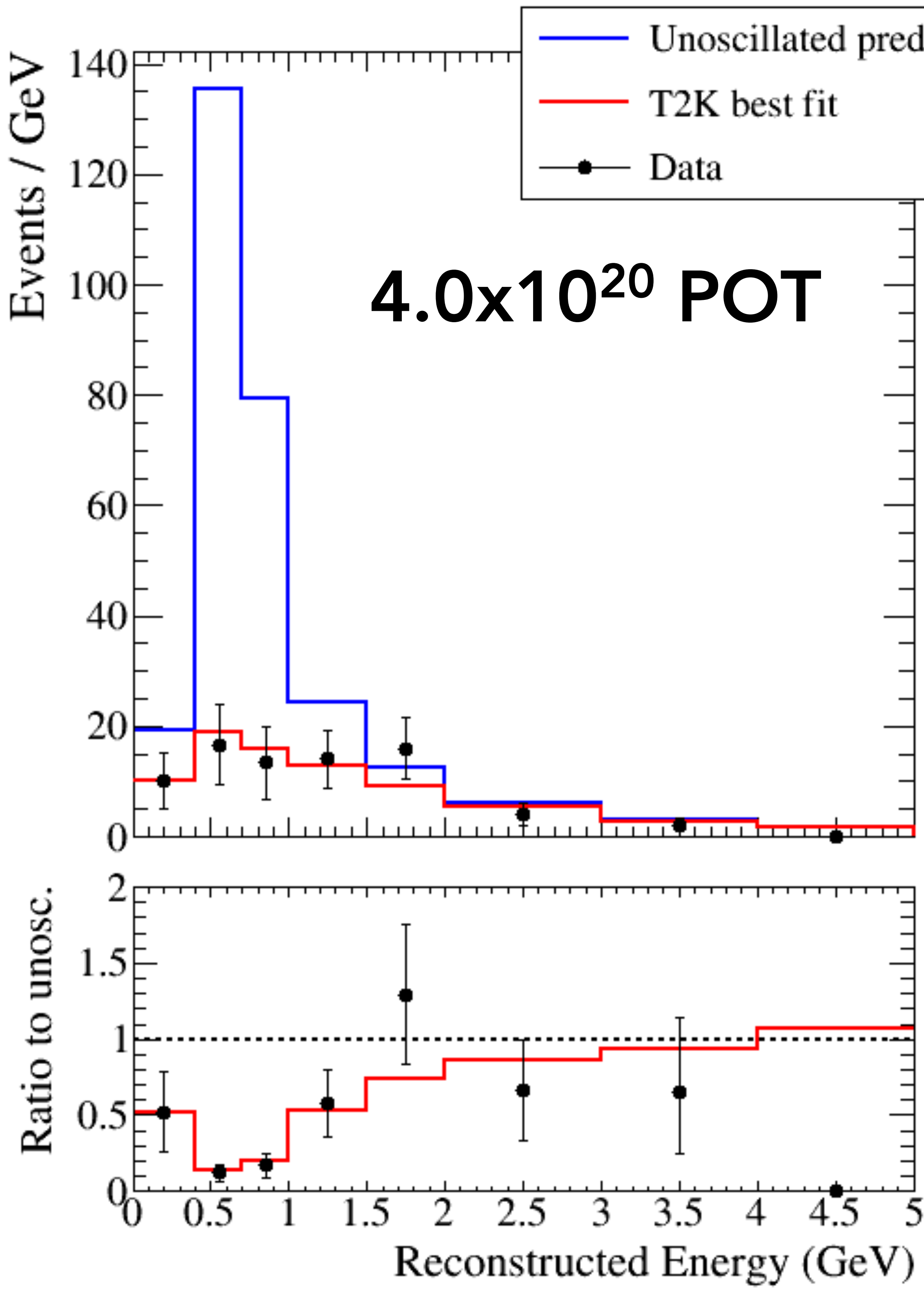
- With θ_{13} from reactor experiment, large ν_e appearance slightly prefers:
  - Normal Hierarchy, $\theta_{23} > \pi/4$
  - $\delta_{CP} \sim -\pi/2$,

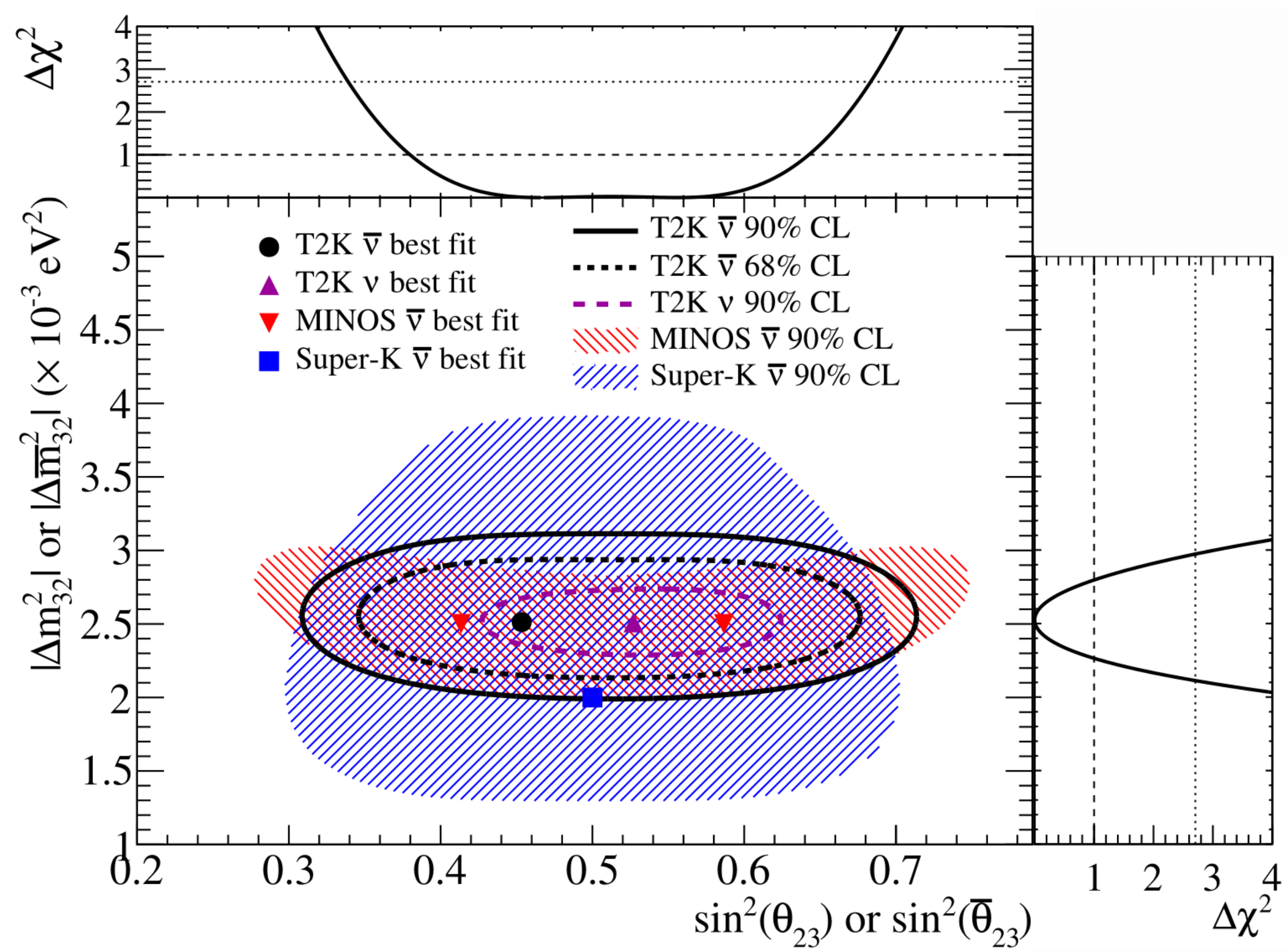
	NH	IH	SUM
$\sin^2\theta_{23} \leq 0.5$	0.179	0.078	0.257
$\sin^2\theta_{23} > 0.5$	0.505	0.238	0.743
SUM	0.684	0.316	1.000

Bayesian posterior probabilities

SINCE THEN . . .

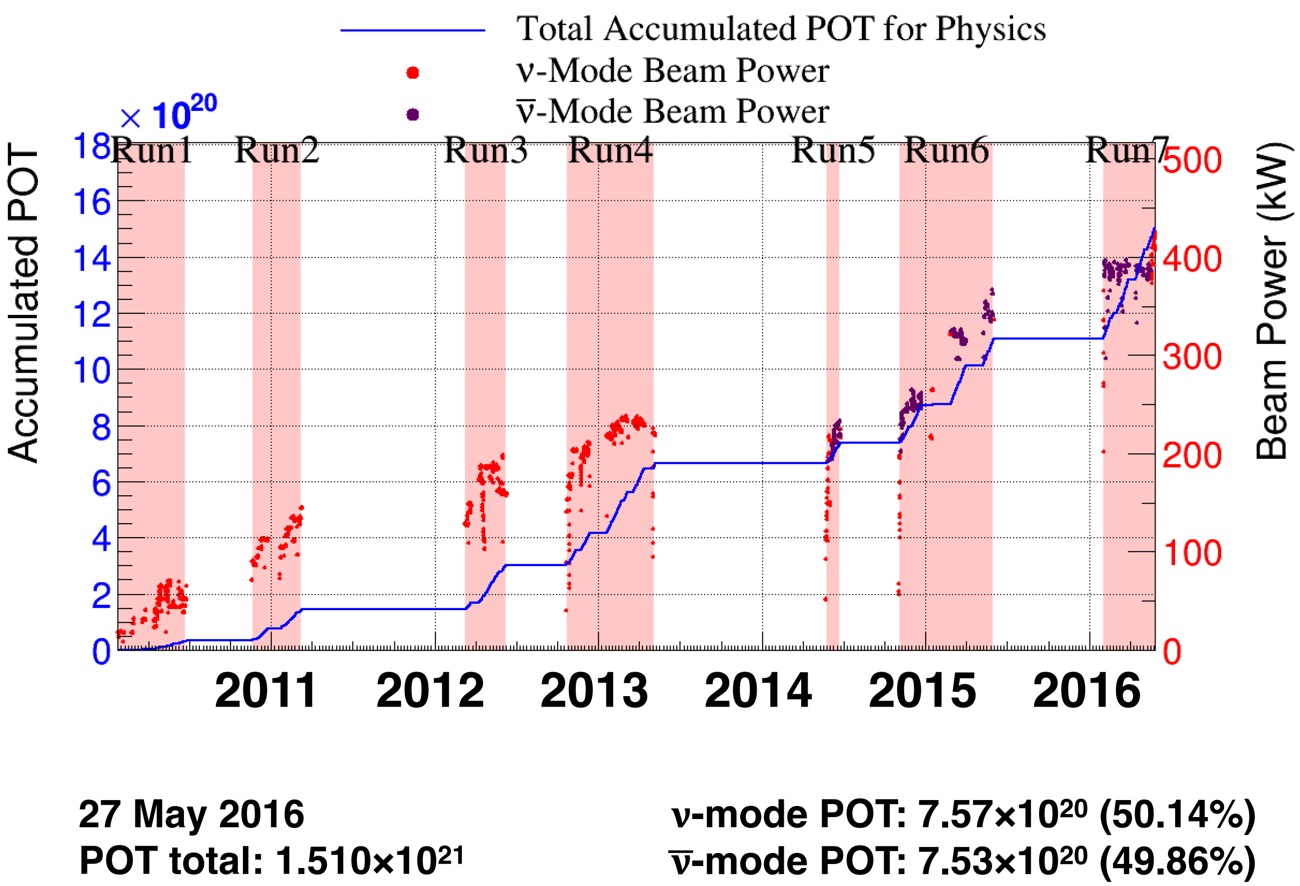
FIRST ANTINEUTRINO RESULTS

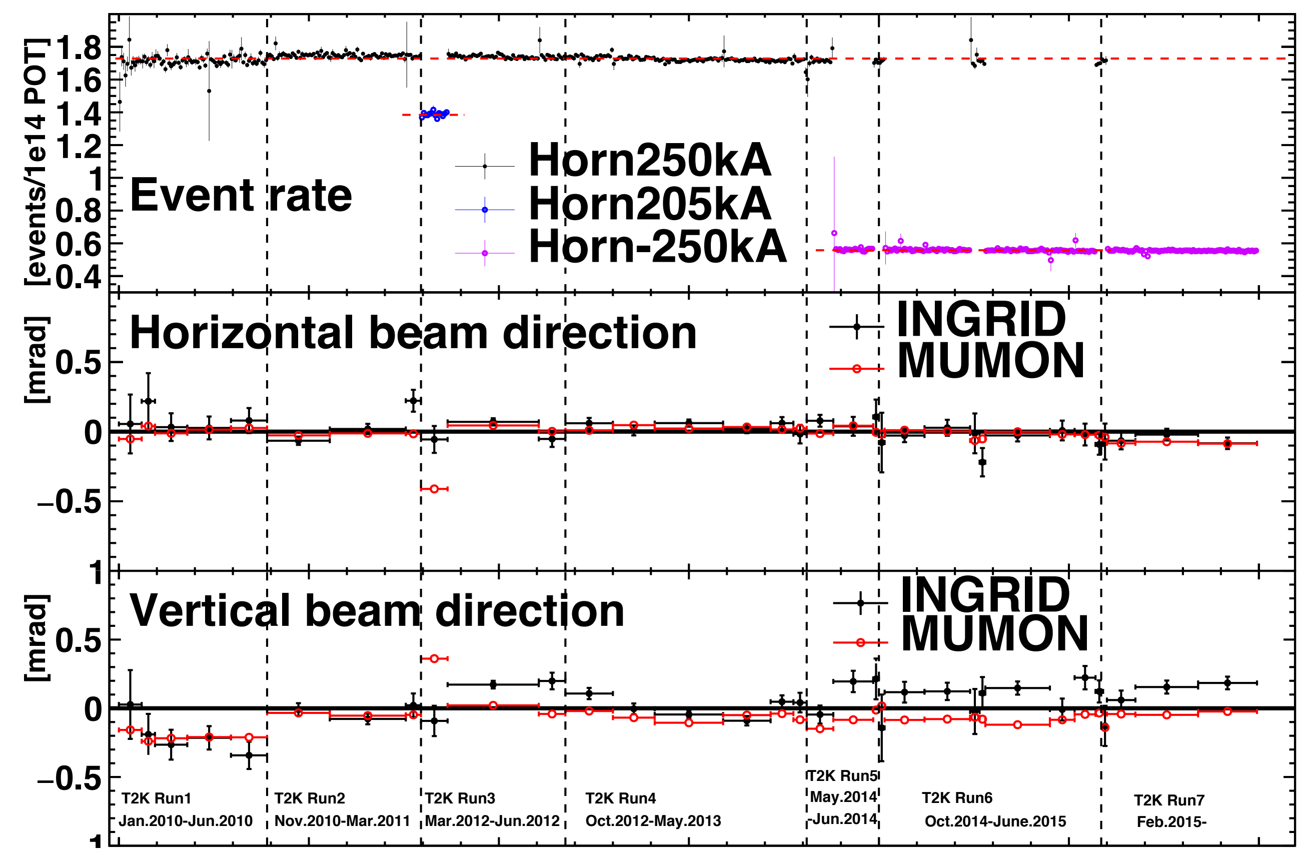




- 2015 $\bar{\nu}_\mu$ disappearance analysis
  - Competitive measurement of antineutrino disappearance parameters with 1 year of data.
  - Phys.Rev.Lett. 116 (2016) no.18, 181801
- $\bar{\nu}_e$ appearance results
  - 3 events observed
  - 3.2 expected with current best-fit values (δ_{CP}~ -π/2)

MORE DATA

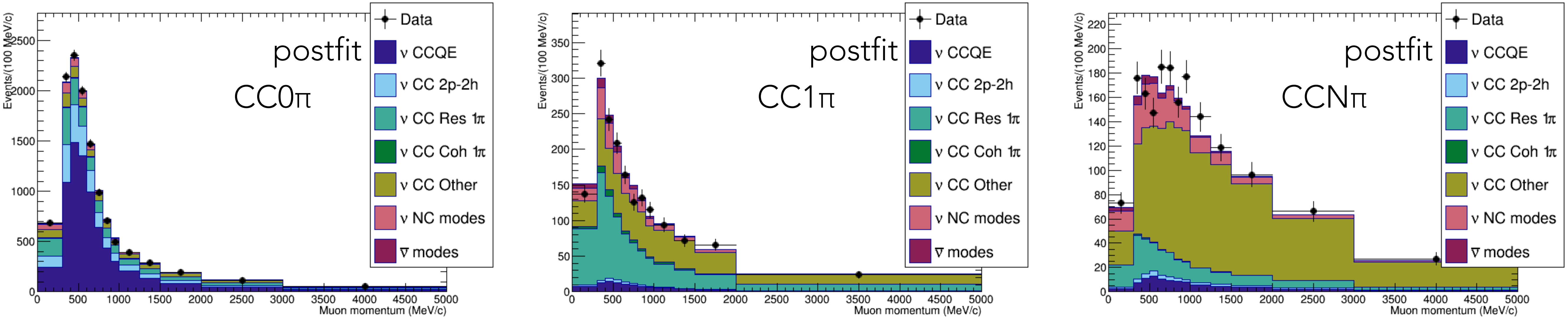




- Continuous rise in beam power from ~225 kW (2014) to 420 kW (2016)
  - Stable beam operations from muon monitor and INGRID measurements
- Total of 15.1×10^{20} POT accumulated as of end of May
- Results presented today with:
  - ν-mode: 7.00×10^{20} POT
  - $\bar{\nu}$-mode: 7.47×10^{20} POT (~2 x previous $\bar{\nu}$-mode results)

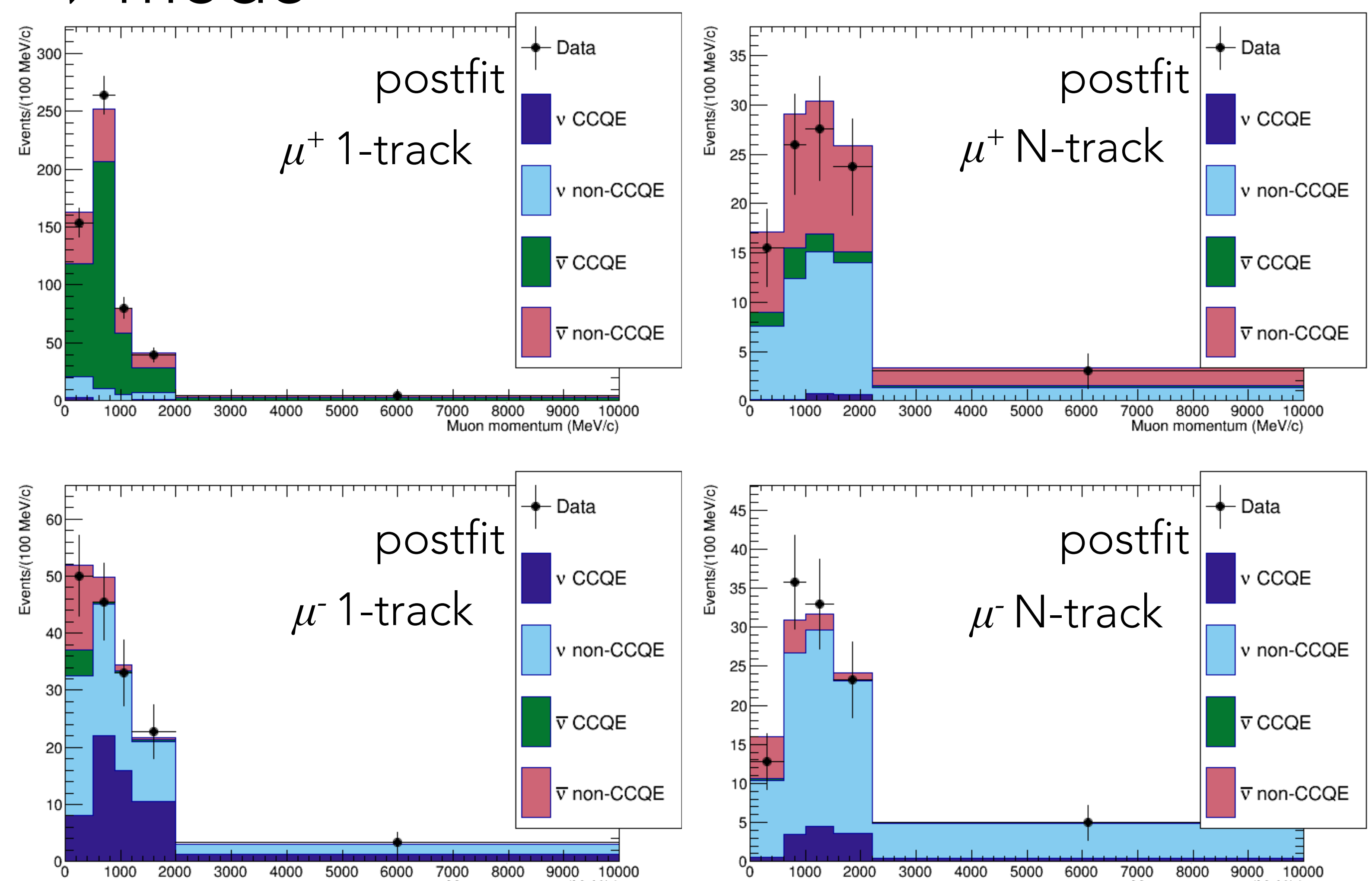
NEAR DETECTOR SAMPLES

P1.036 C. Riccio



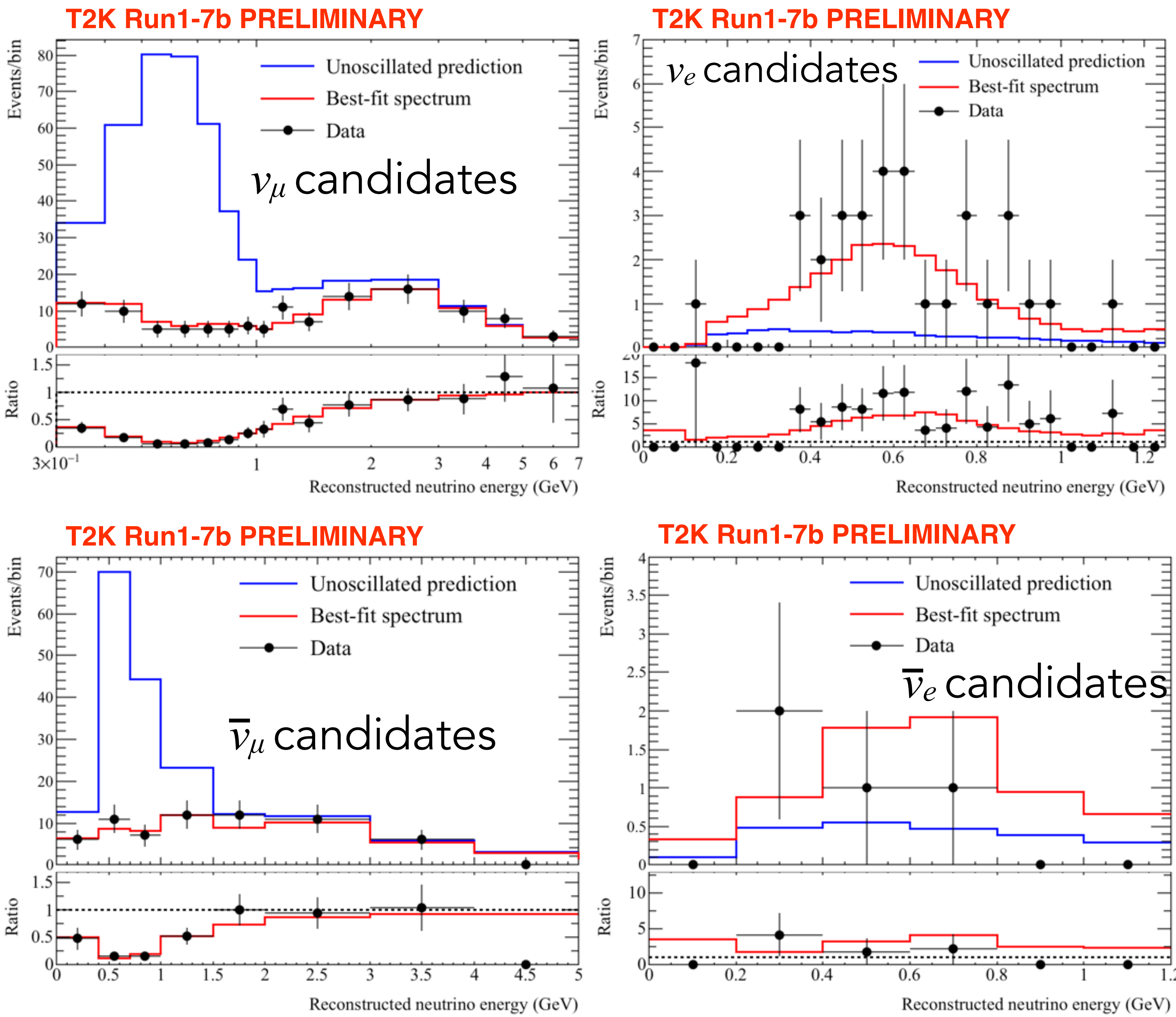
ν-mode

$\bar{\nu}$-mode



- 6 ν-mode samples (FGD1,2) 5.8x10^{20} POT
  - ν_μ CC0π, CC1π, CCnπ
- 8 $\bar{\nu}$-mode samples (FGD1,2) 2.8x10^{20} POT
  - $\bar{\nu}_\mu$ CC 1-track, CC N-track + ν_μ “wrong sign”
- simultaneous fit of μ momentum/angle:
  - FGD1 (all plastic) and FGD2 (water+plastic)
  - Flux parameters increase by ~15%
  - Cross sections ~consistent with input
- P-value = 8.6%
- Reduce uncertainties from 12-15% to 5-8%

EVENTS AT SUPER-KAMIOKANDE



E_{rec} distributions assuming 2-body ("QE") kinematics

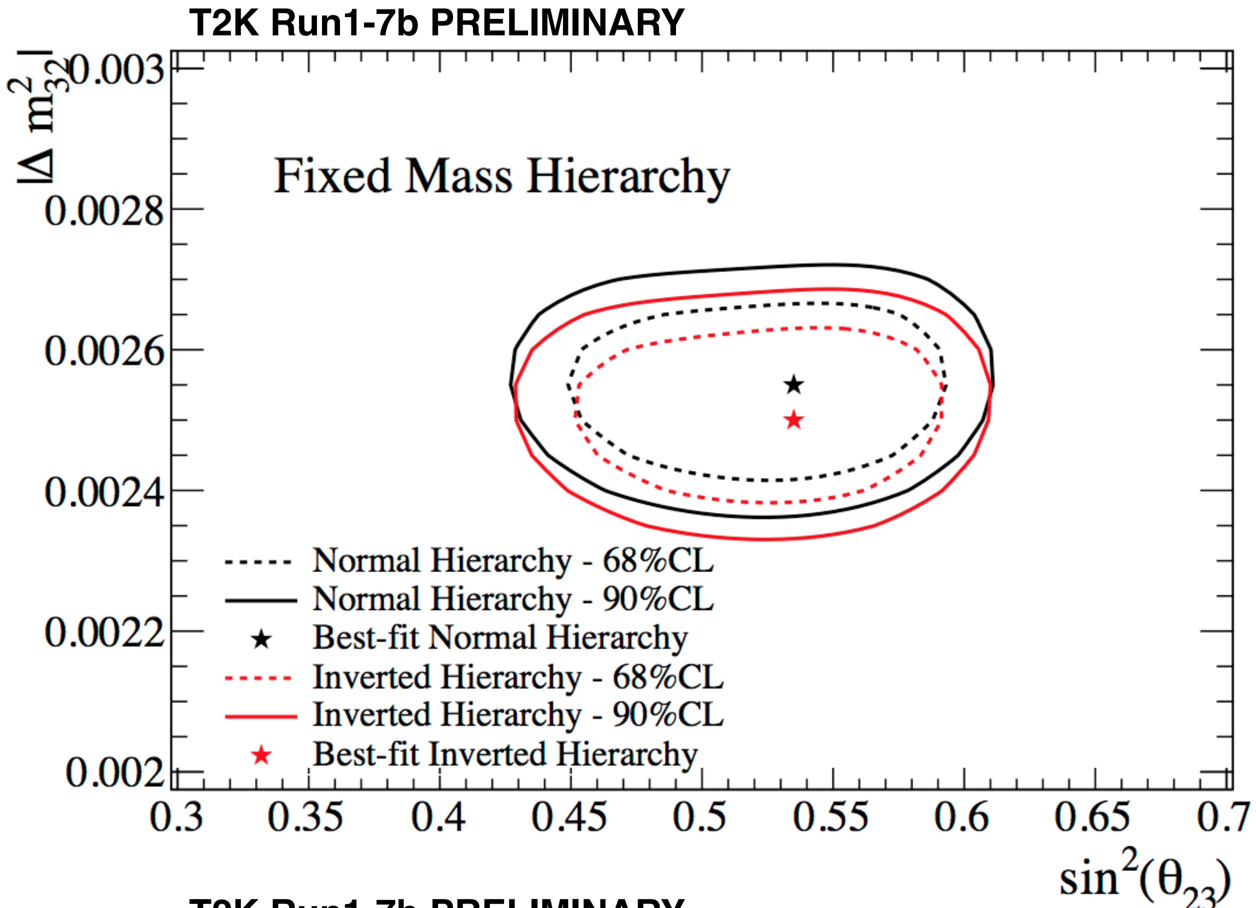
P1.041 R. Shah

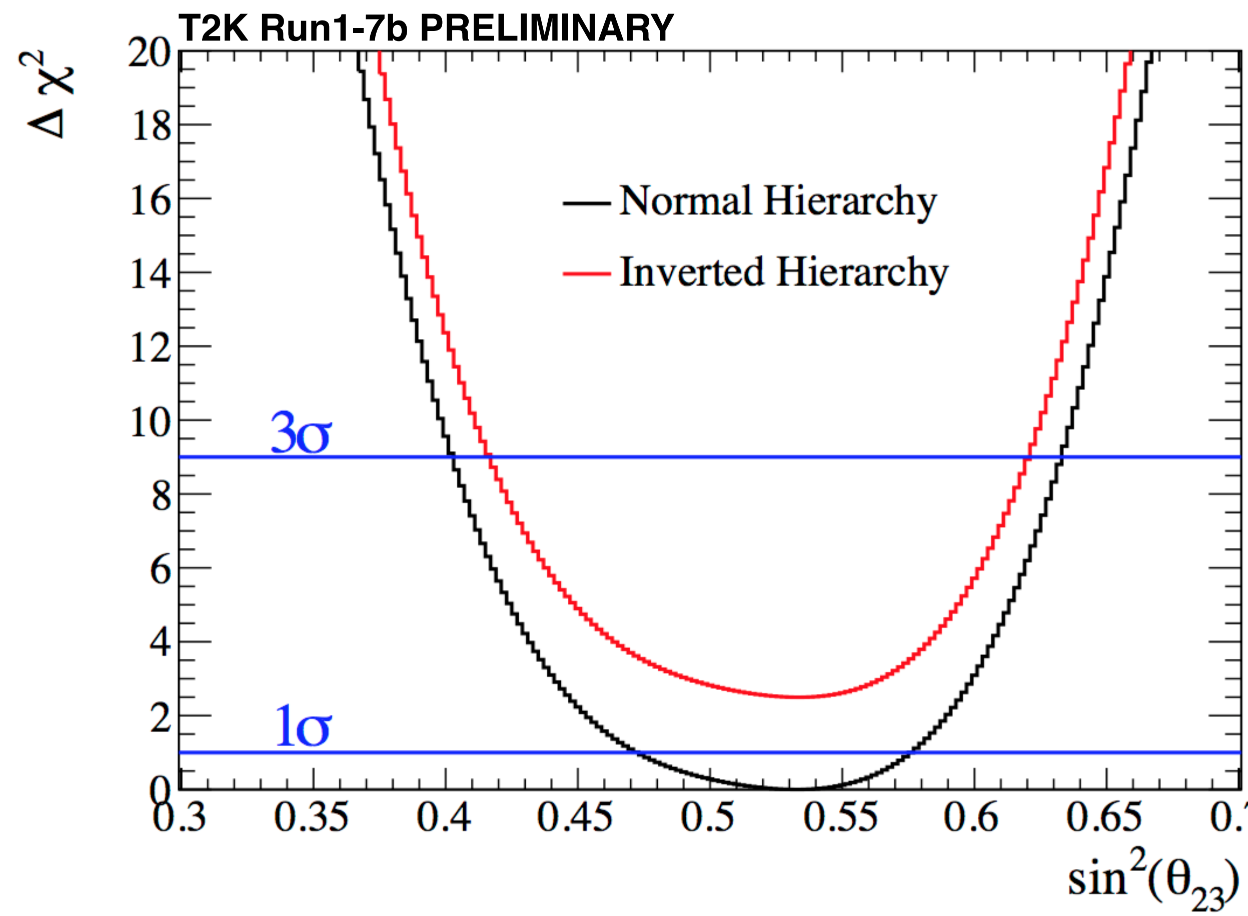
	OBS.	EXP. (NH, $\sin^2\Theta_{23}$=0.528, NH)			
		$\delta_{CP}=-\pi/2$	$\delta_{CP}=0$	$\delta_{CP}=+\pi/2$	$\delta_{CP}=\pi$
ν_μ	125	127.9	127.6	127.8	128.1
ν_e	32	27.0	22.7	18.5	22.7
$\bar{\nu}_\mu$	66	64.4	64.3	64.4	64.6
$\bar{\nu}_e$	4	6.0	6.9	7.7	6.8

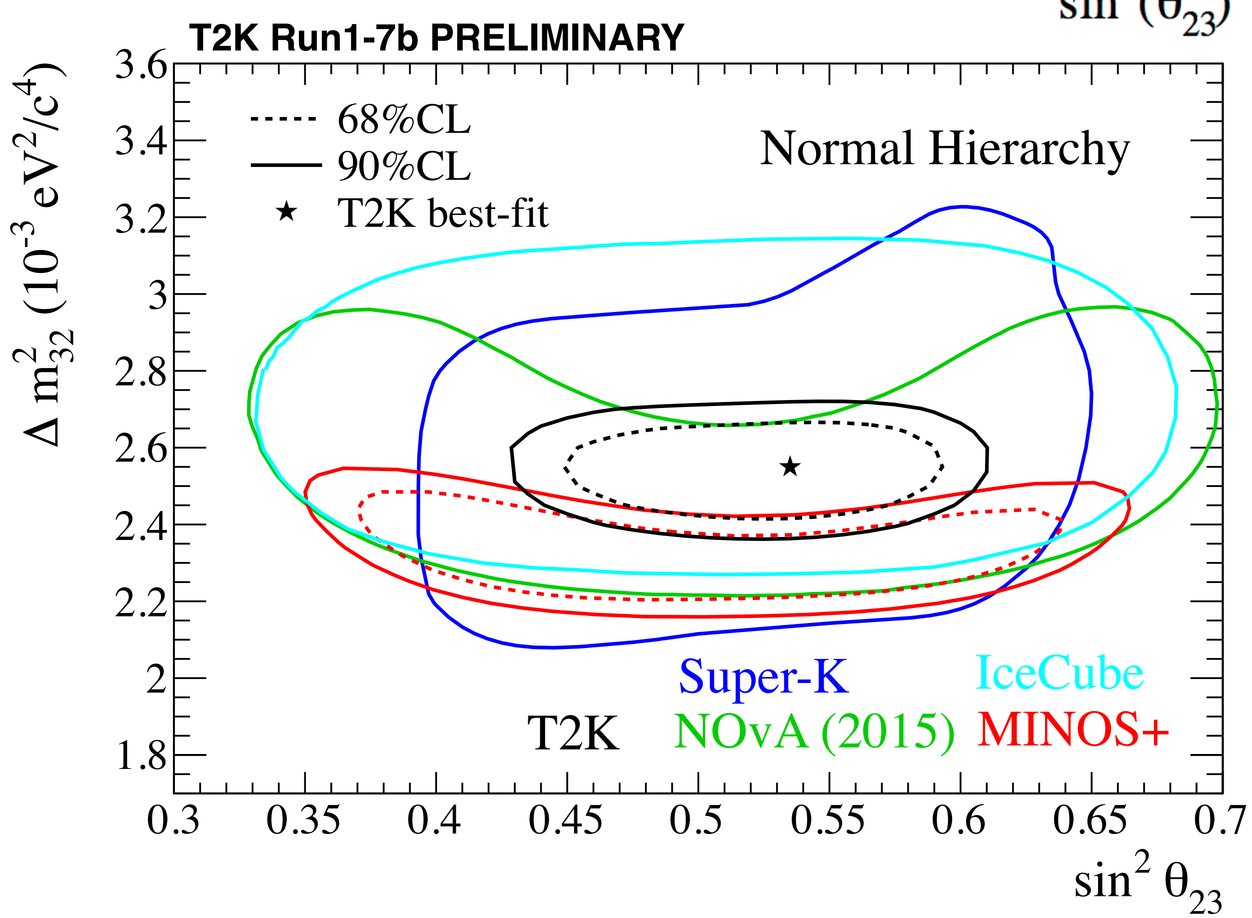
Analysis frameworks

- Frequentist with $\Delta\chi^2$ fit to
  - E_{rec}/θ_{lep} for $\nu_e/\bar{\nu}_e$
  - E_{rec} for $\nu_\mu/\bar{\nu}_\mu$
- Bayesian with likelihood fit to
  - p_{lep}/θ_{lep} for $\nu_e/\bar{\nu}_e$
  - E_{rec} for $\nu_\mu/\bar{\nu}_\mu$
- Bayesian with Markov Chain MC
  - E_{rec} for all samples
  - simultaneous fit with near detector

$\sin^2\theta_{23}$ AND Δm^2_{32}







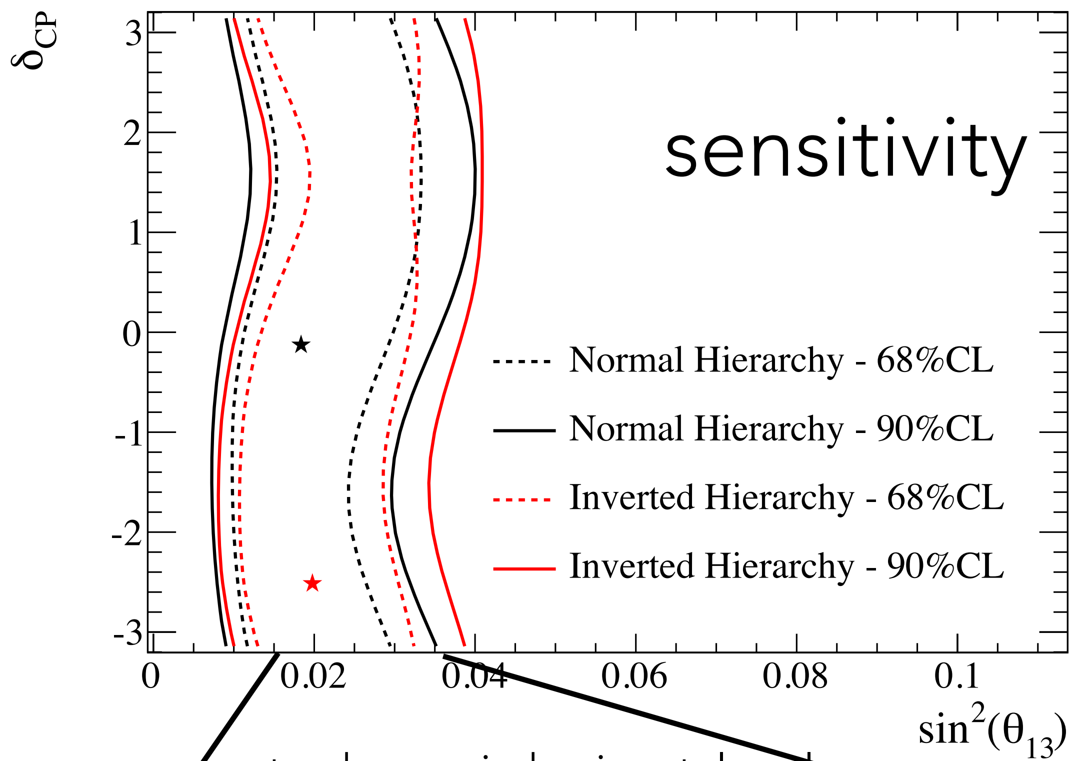
	NH	IH
$\sin^2\theta_{23}$	$0.532^{+0.044}_{-0.060}$	$0.534^{+0.041}_{-0.059}$
$\lvert\Delta m^2_{32}\rvert$ ($/10^{-3}$eV^2)	$2.545^{+0.084}_{-0.082}$	$2.510^{+0.082}_{-0.083}$

- Results continue to be consistent with maximal mixing/oscillation

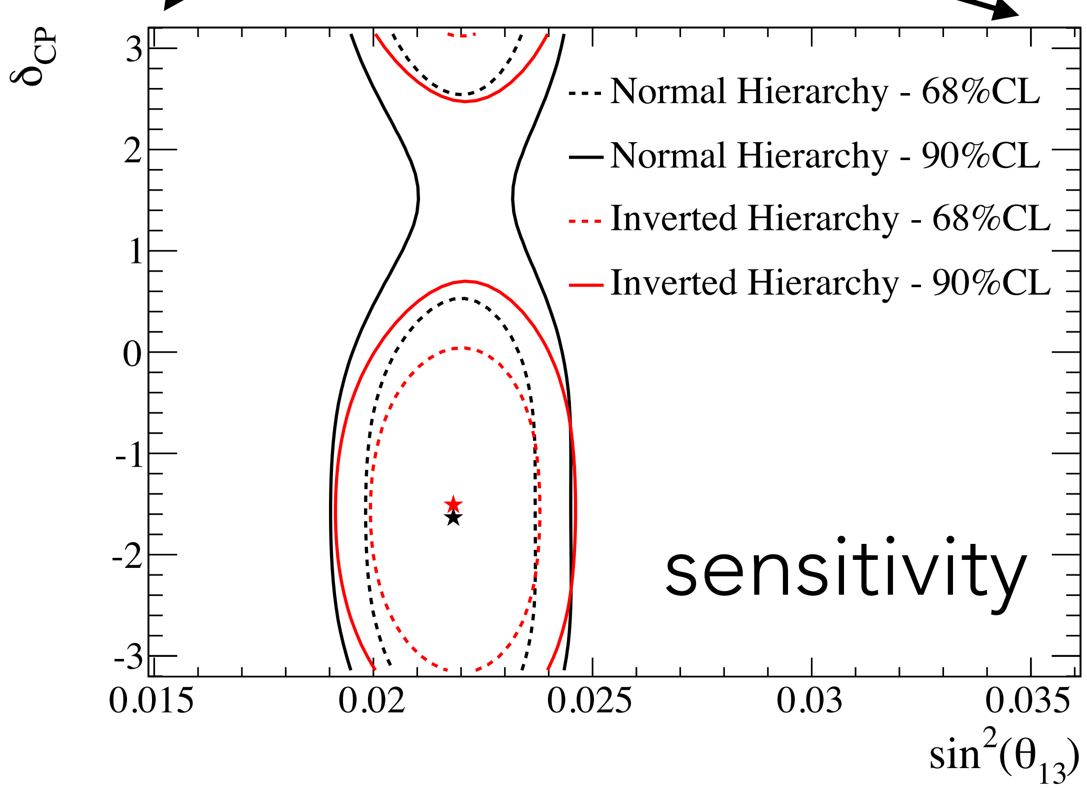
δ_{CP} vs. θ_{13}

sensitivity assumptions:

- $\sin^2 2\theta_{13}$= 0.085 (PDG 2015)
- $\sin^2\theta_{23}$ = 0.528
- NH, δ_{CP} = -1.601



note change in horizontal scale

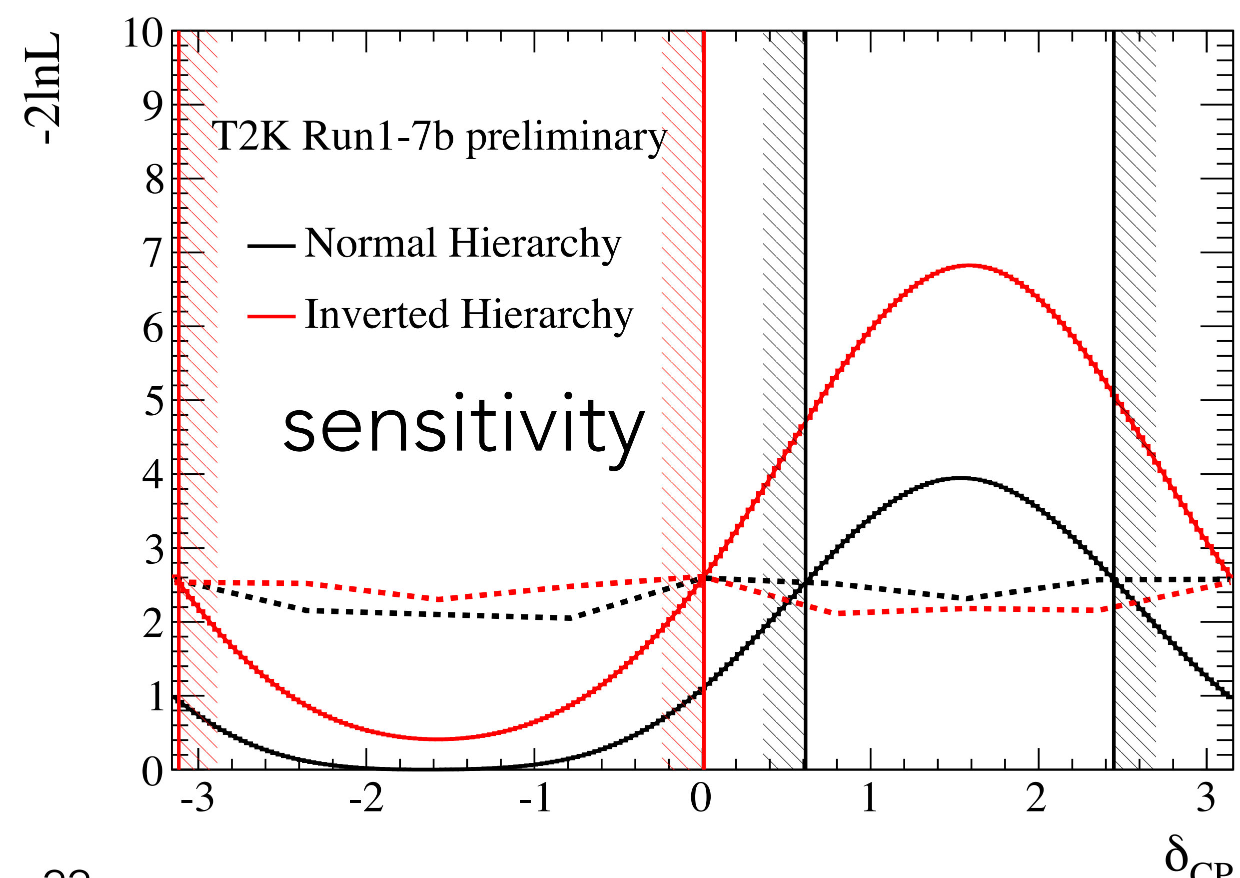


Left: δ_{CP} vs. θ_{13} (fixed $\Delta\chi^2$, fixed hierarchy)

- T2K-only
- T2K with reactor $\sin^2 2\theta_{13}$= 0.085±0.005

Below: δ_{CP} with Feldman-Cousins critical values and reactor θ_{13}

δ_{CP} = [-3.02, -0.49] (NH), [-1.87, -0.98] (IH) @90% CL



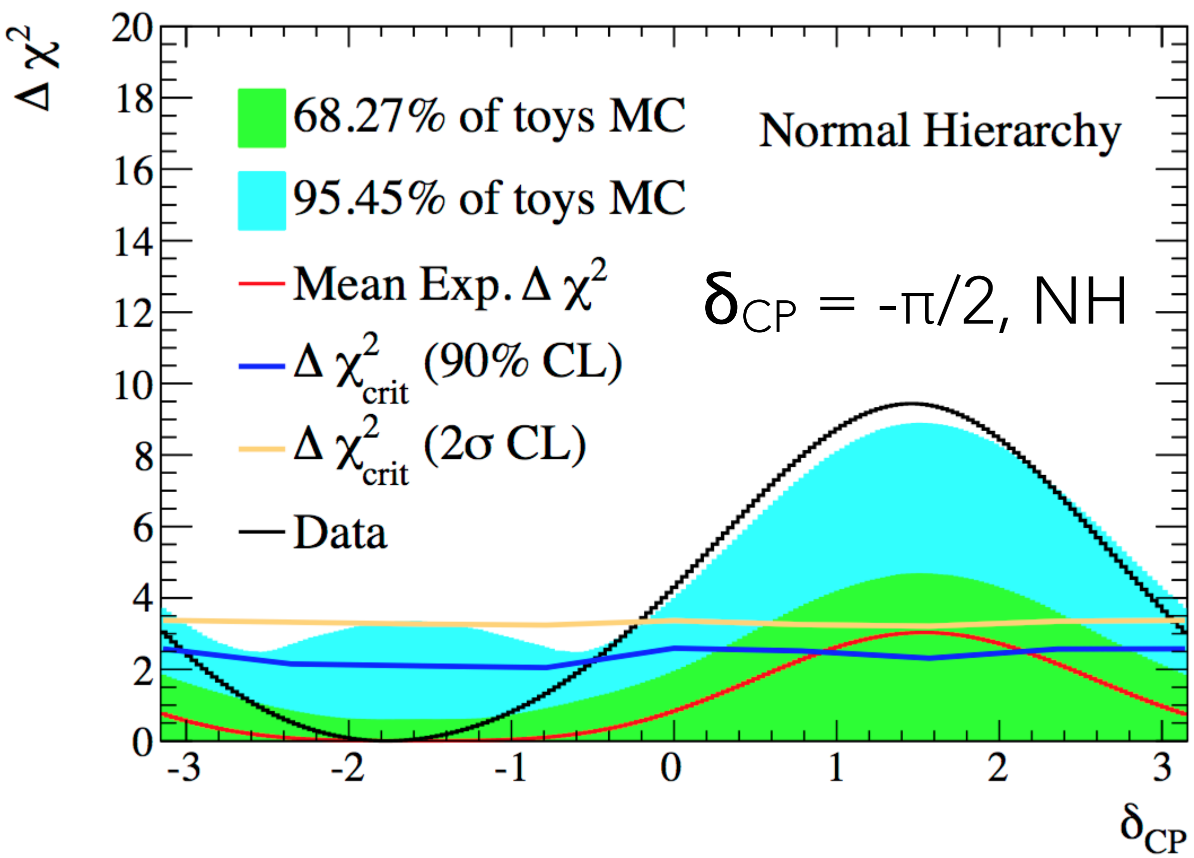
DISCUSSION

- Observe
  - more ν_e candidates than predicted
  - fewer $\bar{\nu}_e$ candidates than predicted

in the case of NH, δ_{CP} = -π/2 that induces the largest asymmetry

observed vs. expected number of ν_e and ν_e candidates

		EXPECTED (NH, $\sin^2\Theta_{23}$=0.528)			
	OBS.	δ_{CP}=-π/2	δ_{CP}=0	δ_{CP}=+π/2	δ_{CP}=π
ν_e	**32**	27.0	22.7	18.5	22.7
$\bar{\nu}_e$	**4**	6.0	6.9	7.7	6.8

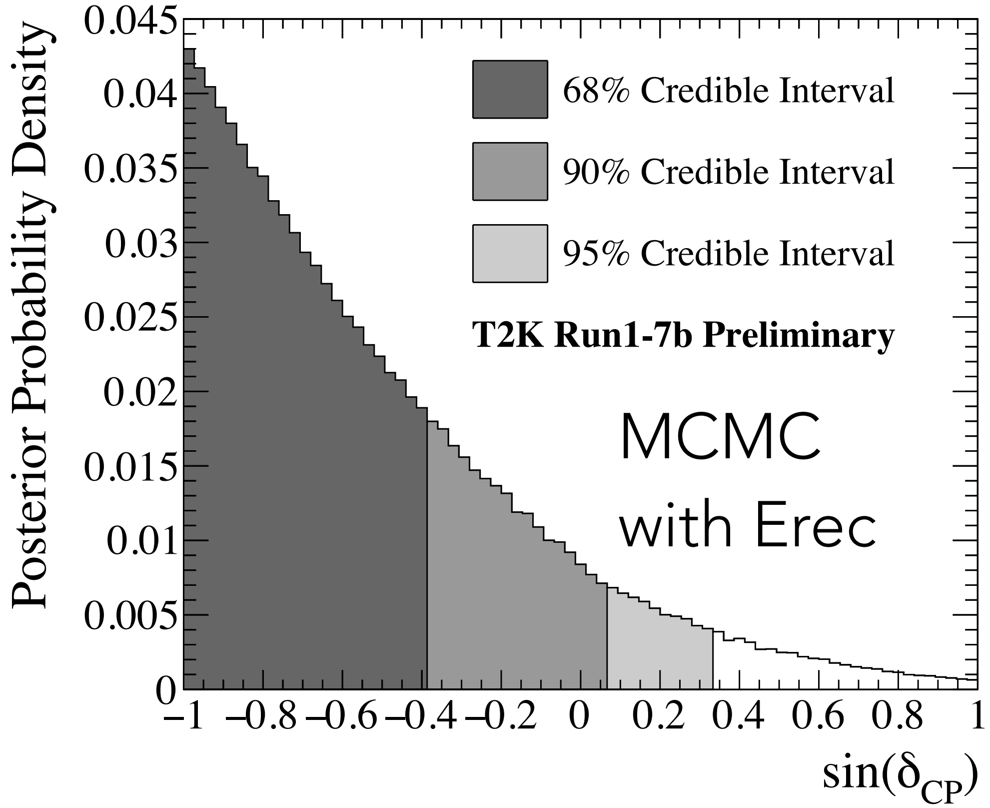


- Toy MC run to assess probability of outcome given a set of "true" parameters
- Below: fraction where δ_{CP} =0 excluded at 90% or 2 σ CL for NH, δ_{CP} = -π/2, 0

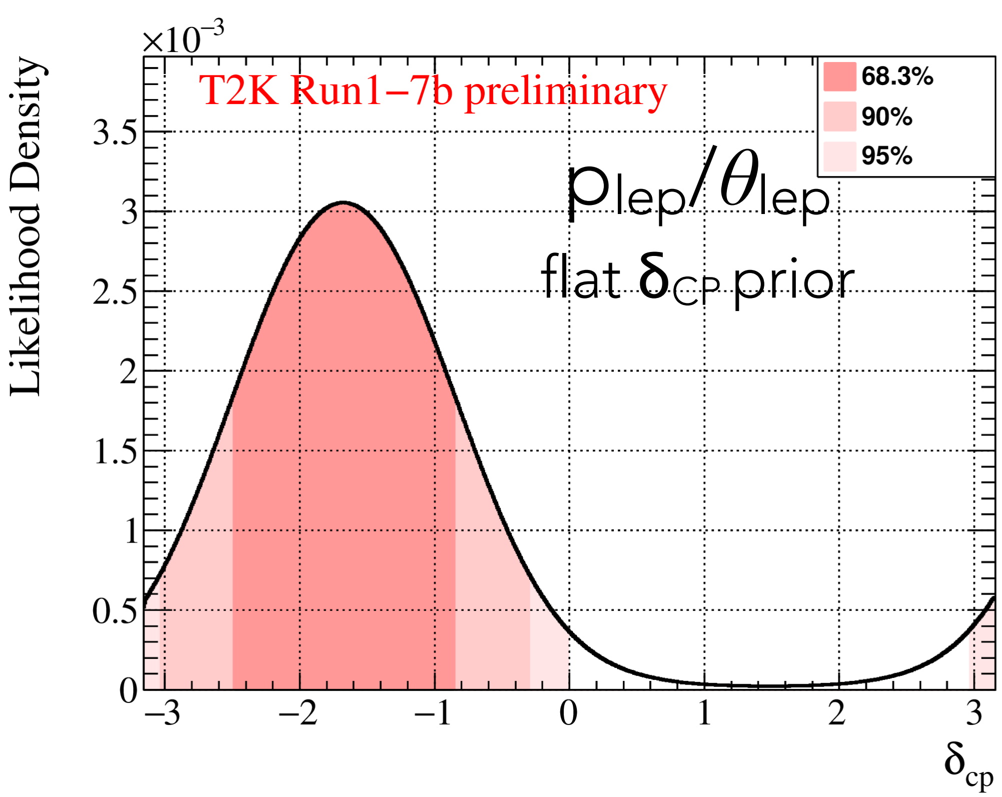
	TRUE PARAMETERS	
	δ_{CP}=-π/2, NH	δ_{CP}=0, NH
90%	0.187	0.102
2 σ	0.089	0.047

BAYESIAN POSTERIOR PROBABILITIES

P4.023 K. Duffy



- Left: posterior probability distribution in δ_{CP} marginalizing over all other parameters
  - negligible dependence on priors except for δ_{CP}
    - (flat in δ_{CP} vs. $\sin \delta_{CP}$)
- Bottom: posterior probability distributions for θ_{23} octant and hierarchy with MCMC analysis
  - mild preference for $\theta_{23} > \pi/4$ and normal hierarchy

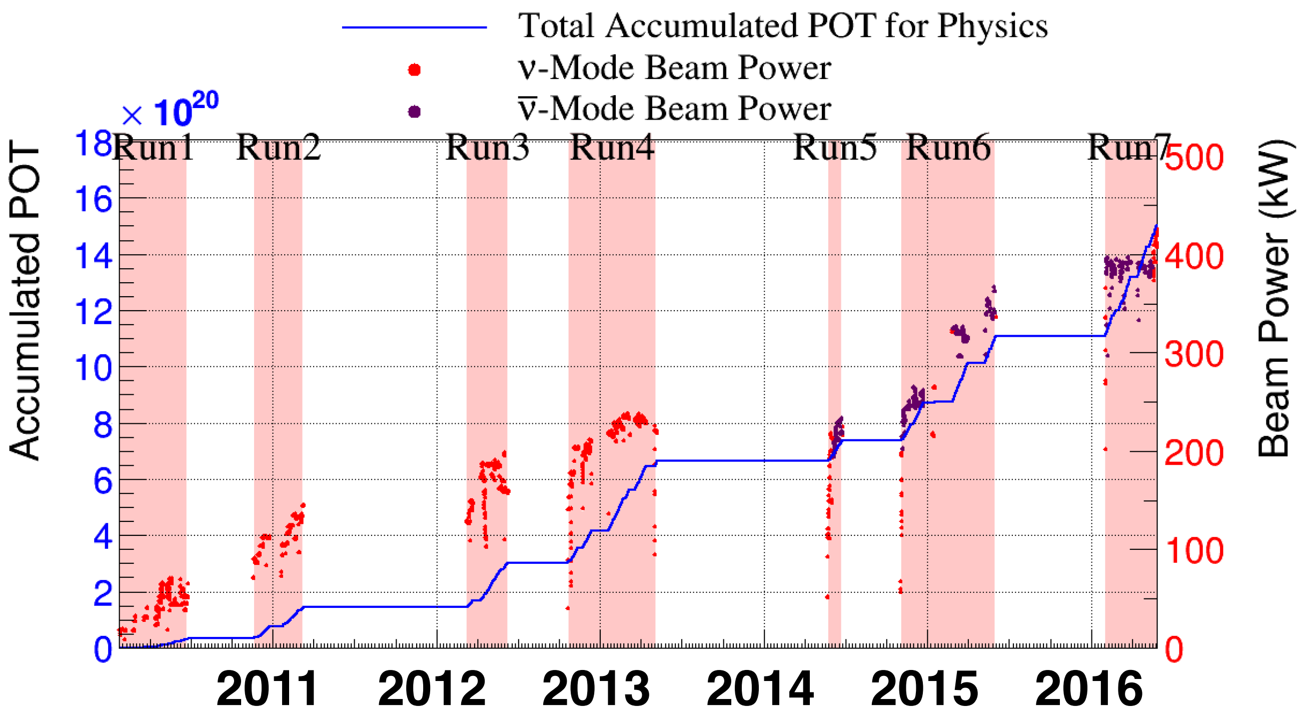


	NH	IH	SUM
$\sin^2\theta_{23} \leq 0.5$	0.218	0.072	0.290
$\sin^2\theta_{23} > 0.5$	0.529	0.181	0.710
SUM	0.747	0.253	1.000

NEXT TIME ON T2K

PROSPECTS

Sat. Talk by M. Friend

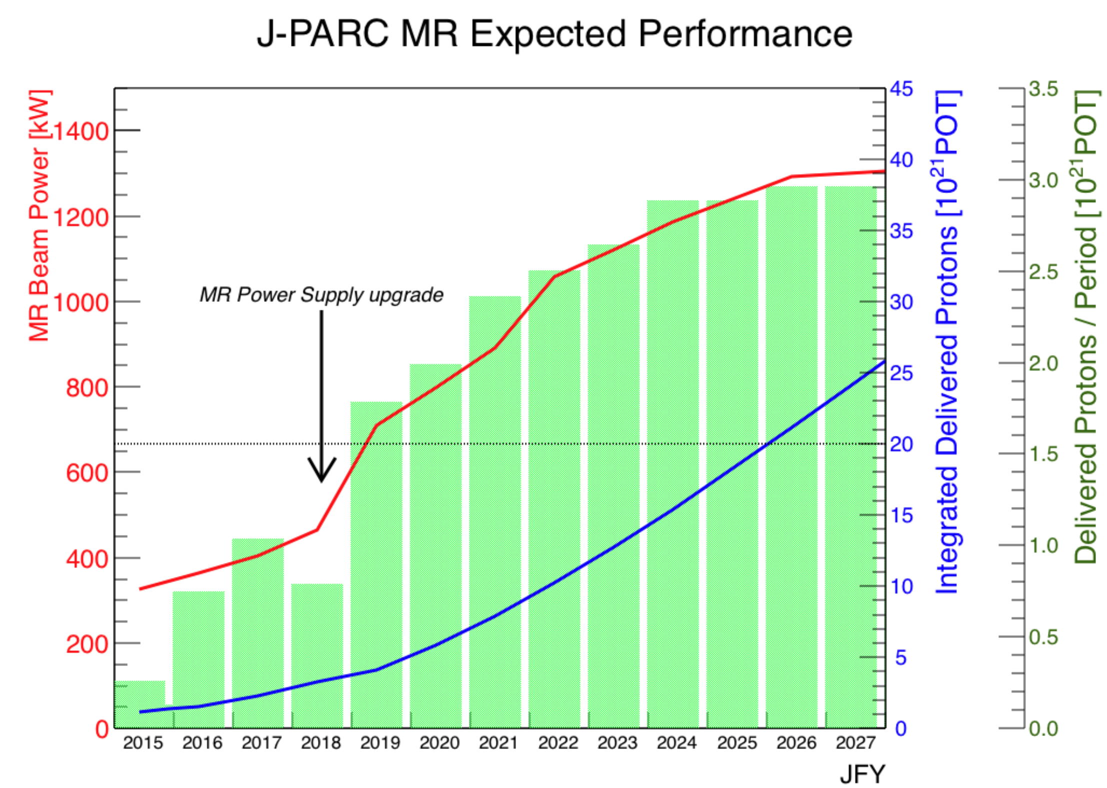


27 May 2016
POT total: 1.510×10^21

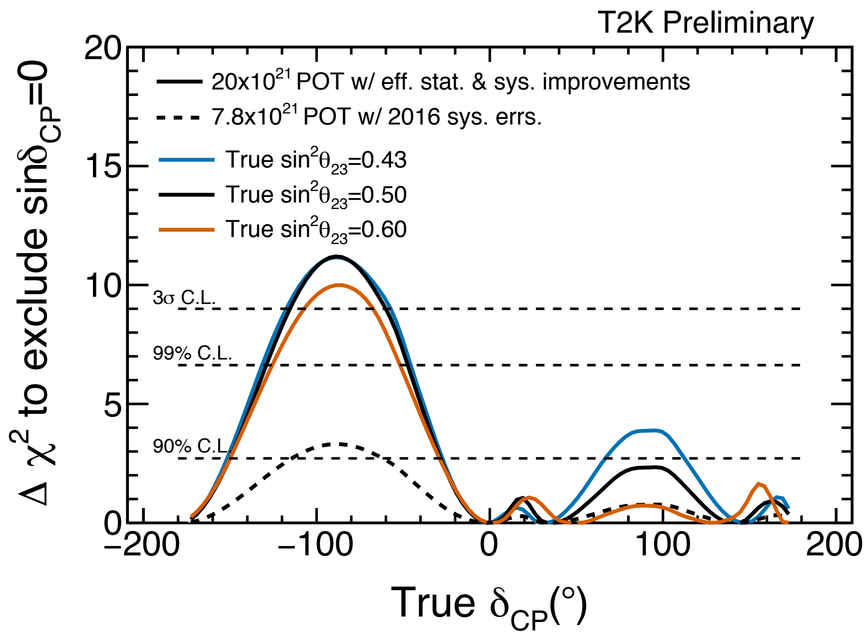
ν-mode POT: 7.57×10^20 (50.14%)
ν̄-mode POT: 7.53×10^20 (49.86%)

JFY	2014	2015	2016	2017	2018	2019	2020
	Li. current upgrade		New PS buildings				
FX power [kW] (study/trial)	320	> 360	400	450	700	800	900
SX power [kW] (study/trial)	-	33 - 40	50	50-70	50-70	~100	~100
Cycle time of main magnet PS New magnet PS	2.48 s R&D	Large scale 1st PS	Mass production installation/test		1.3 s	1.3 s	1.2 s
High gradient rf system 2nd harmonic rf system VHF cavity	Manufacture, installation/test R&D	R&D, manufacture, installation/test					
Ring collimators		Add.collimators (2 kW)	Add.collimators (3.5kW)				
Injection system FX system	Kicker PS improvement, Septa manufacture /test Kicker PS improvement, LF septum, HF septa manufacture /test						
SX collimator / Local shields		Local shields					
Ti ducts and SX devices with Ti chamber	Beam ducts	ESS					

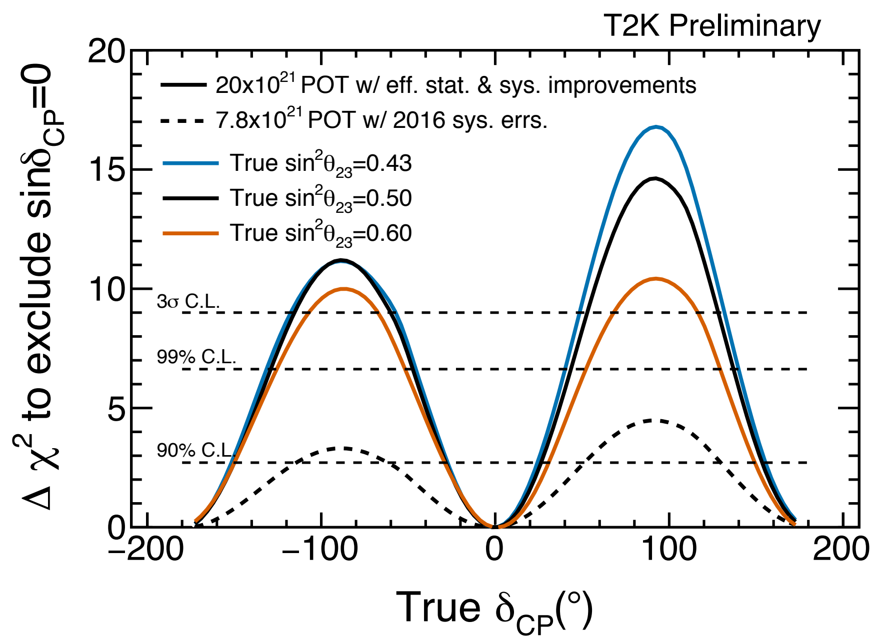
- 1st stage of J-PARC MR power supply upgrades approved
  - reduce cycle from 2.48 s to 1.3 s: 420 kW (current) → ~800 kW
  - Now aiming for > 1 MW capability
- "T2K-II"
  - extension of T2K run to 20x10^21 POT on the time scale of 2026
    - currently approved for 7.8x10^21 POT (~2021)
  - accelerator and beam line upgrades to reach 1.3 MW



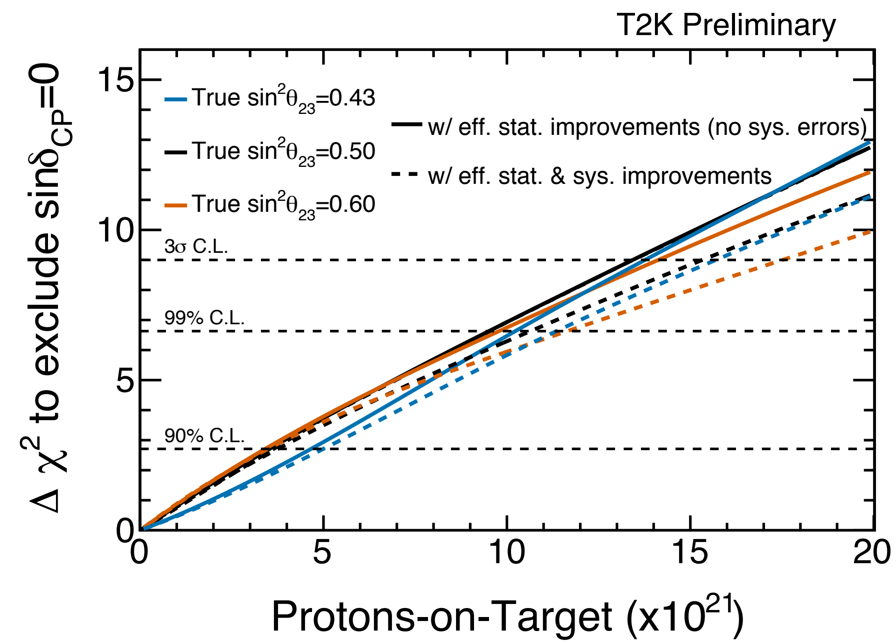
T2K-II: PHYSICS POTENTIAL



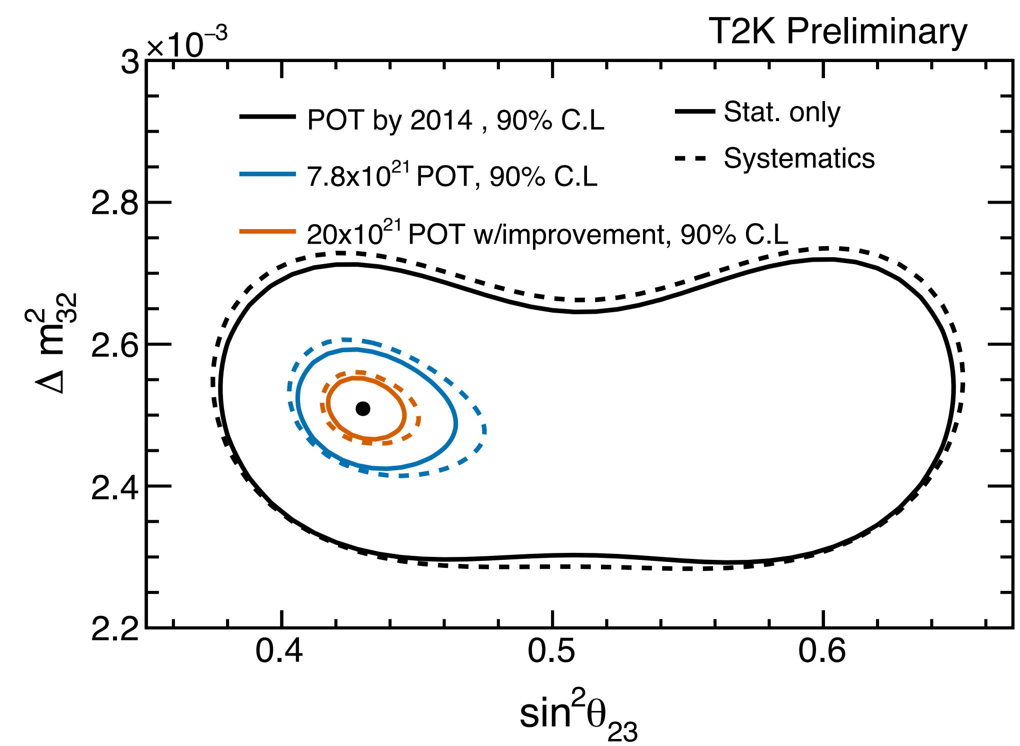
hierarchy unknown



external hierarchy input



- Assumes ~50% increase in effective statistics/POT
  - increase horn current to design (320 kA): ~+10%
  - SK multi-ring samples and fiducial volume increase: ~+40%
  - reduction of systematic errors ***P3.025 B. Quilain***
- ~3 σ sensitivity to CP violation for favourable (and currently favoured) parameters
- Precise measurement of θ_{23}:
  - octant resolution if θ_{23} at edge of currently allowed values
  - otherwise, measure θ_{23} to ~1.7° or better



P4.022 M. Friend

CONCLUSIONS

- Steadily improving beam power with 420 kW achieved at end of FY 2015
  - Accumulated ~15×10^{20} POT split equally in ν- and $\bar{\nu}$-mode
- First fully joint analysis across all modes of oscillation
  - $\nu_\mu/\bar{\nu}_\mu$ disappearance, $\nu_e/\bar{\nu}_e$ appearance
  - incorporate water target and “wrong sign” constraints from near detector
  - data continues to prefer maximal θ_{23} mixing, δ_{CP} ~-π/2, normal hierarchy
    - “maximal” $\nu_\mu/\bar{\nu}_\mu$ disappearance, “large” ν_e appearance, “small” $\bar{\nu}_e$ appearance
    - δ_{CP} = [-3.02, -0.49] (NH), [-1.87, -0.98] (IH) @ 90% CL
- First stage of upgrades for >700 kW operations approved.
- Propose to extend T2K with
  - accelerator and beamline upgrades to support 1.3 MW beam
  - running to ~2026 to accumulate 20×10^{21} POT (3x currently approved POT)
  - Primary goals aimed at >3 σ sensitivity to CPV, θ_{23} measured to <1.7°
- T2K physics program is very broad: many new developments not discussed here
  - Please see our extensive (23) poster program

POSTERS

T. HAYASHINO	Anti-neutrino beam direction and intensity measurement	P1.036 MON.
A. KNOX	Estimating the pion and kaon contributions to the T2K neutrino beam	P1.037 MON.
M. POSIADALA	Recent T2K flux predictions with NA61/SHINE thin graphite target measurements	P1.038 MON.
C. RICCIO	Muon neutrino and antineutrino selection in the tracker of the T2K off-axis near detector	P1.039 MON.
A. MISSERT	Improving T2K oscillation analyses using fiTQun	P1.040 MON.
R. SHAH	Muon antineutrino disappearance and electron antineutrino appearance searches	P1.041 MON.
D. SHAW	A CCPi0 inclusive analysis at the T2K near detector	P1.042 MON.
L. ZAMBELLI	Towards T2K neutrino flux predictions using replica target measurements by NA61/SHINE	P1.043 MON.
B. QUILAIN	The WAGASCI detector as an off-axis near detector of the T2K and HK experiments	P3.025 WED.
L. KOCH	Measurement of neutrino interactions in gaseous argon with T2K	P3.029 WED.
P. LASORAK	A search for neutral-current single photons with the ND280 at T2K	P3.031 WED.
W. MA	Current status of final state interactions models . . .	P3.032 WED.
P. MARTINS	Charged-current coherent pion production on oxygen nuclei in the T2K near detector	P3.033 WED.
J. ZALIPSKA	Reconstruction of low momentum protons with FGD of the T2K experiment	P3.034 WED.
D. COPLOWE	Resonance production cross-section measurement in neutrino-H interactions . .	P3.035 WED.
S. BORDONI	CCmuon neutrino shape and rate analysis at the T2K off-axis near detector	P3.074 WED.
T. VLADISAVLJEVIC	Probing Nuclear Effects at the T2K Near Detector Using Transverse Kinematic Variables	P3.097 WED.
A. IZMAYLOV	Search for heavy neutral leptons with the near detector complex . . .	P4.014 FRI.
M. FRIEND	Physics sensitivity of a possible extended T2K Run -- T2K phase 2	P4.022 FRI.
K. DUFFY	First joint analysis of neutrino and antineutrino oscillation at T2K	P4.023 FRI.
J. LAGODA	Probing K-originated neutrinos with the muons produced outside of ND280	P4.024 FRI.
G. CHRISTODOULOU	Measurement of electron (anti-)neutrinos at the T2K near detector	P4.025 FRI.
C. WRET	Single-pion production in the NEUT neutrino interaction generator	P4.029 FRI.

more details and topics! Please see!