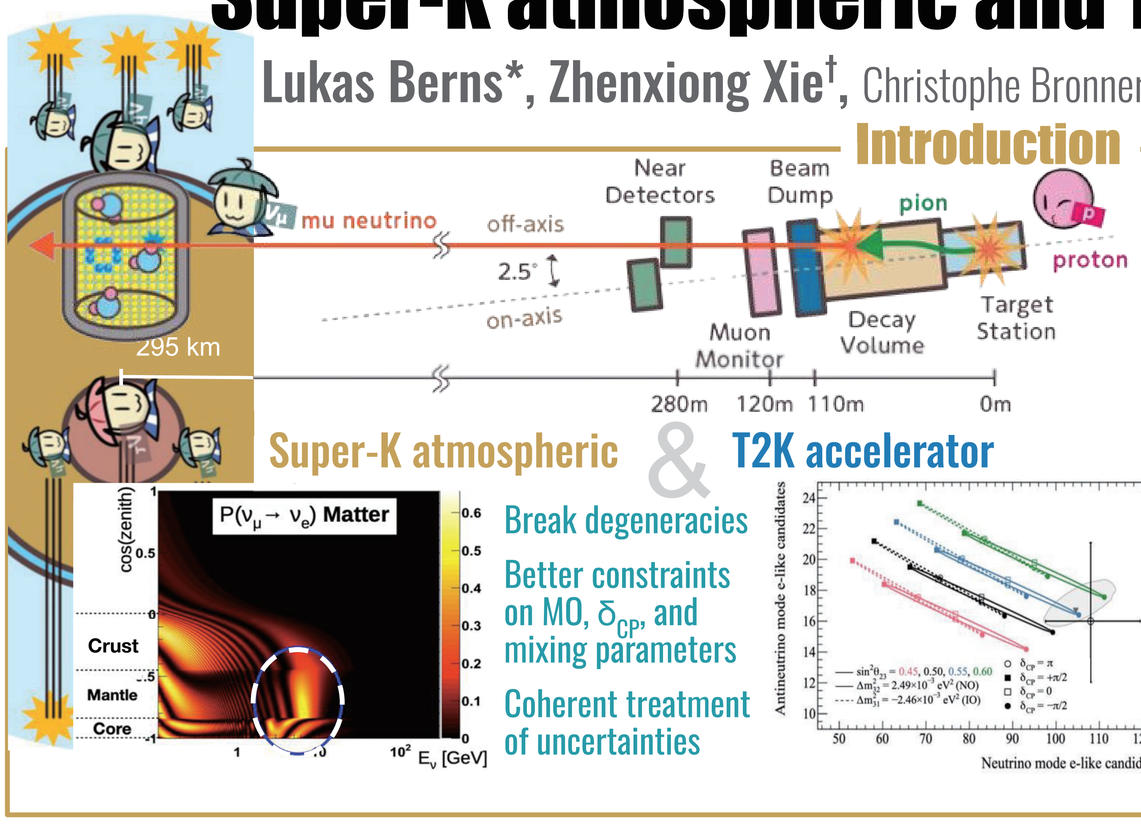
Frequentist results from **First joint analysis of**

Super-K atmospheric and T2K accelerator neutrino data

Lukas Berns*, **Zhenxiong Xie**†, Christophe Bronner, Aoi Eguchi, Jianrun Hu, Roger Wendell, Super-K and T2K Collaborations

Introduction

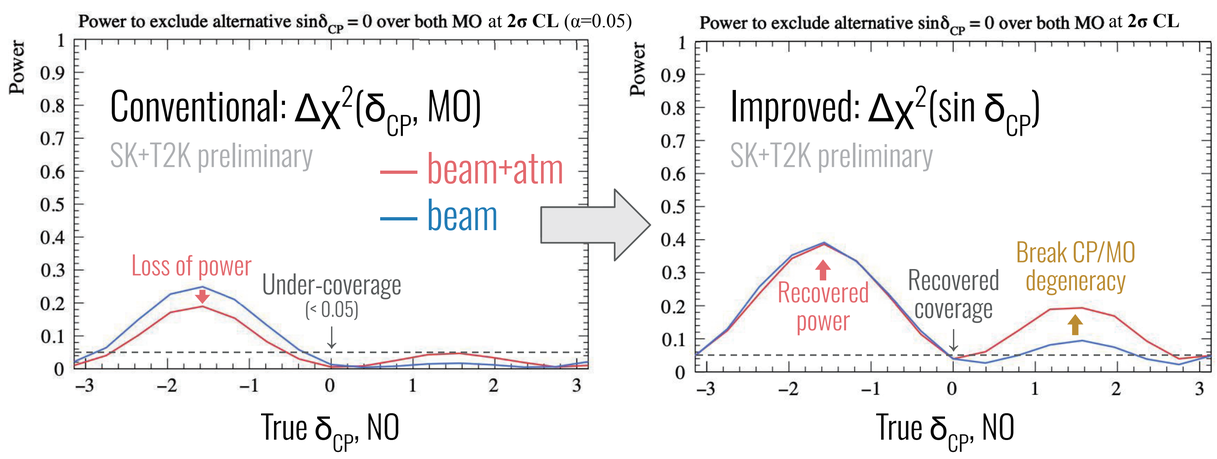


Super-K atmospheric & **T2K accelerator**

- Break degeneracies
- Better constraints on MO, δ_{CP}, and mixing parameters
- Coherent treatment of uncertainties

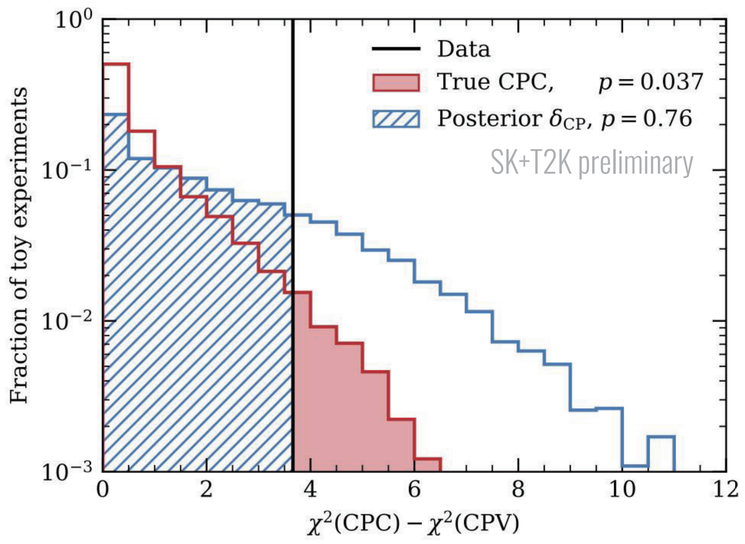
Frequentist statement on CP-conservation

Feldman-Cousins method is used, but choice of test-statistic matters for CPC



Conventional test-statistic has 4 CPC values: (0,NO), (π,NO), (0, IO), (π, IO). Requiring all to be outside of the confidence intervals is equivalent to profiling *after* Feldman-Cousins procedure, which breaks statistical coverage. Leads to paradoxical loss of power in joint fit (because more power to distinguish 4 points).

Improved method profiles over (sgn cos δ_{CP}, MO) *before* Feldman-Cousins:
→ single CPC value: sin δ_{CP} = 0 (here equivalent to Jarlskog invariant = 0)
→ Coverage and power is recovered
→ Joint fit leads to improved sensitivity as expected.



Using new test-statistic, see slightly stronger **exclusion of CPC** (p = 0.037) than beam-only fit (p = 0.047).

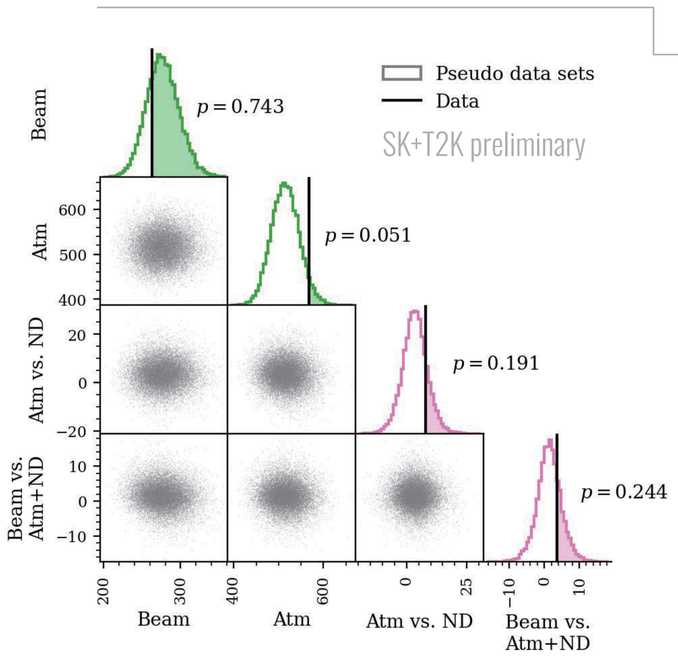
Significance can fall below 2σ CL due to potential weaknesses of the uncertainty model (p = 0.050).

Good agreement with ensemble that allows for **CP-violation** (posterior-distributed δ_{CP} values)

Analysis model and goodness-of-fit

Developed **common cross-section** and **detector uncertainty** model for events of SK and T2K which overlap in energy.

T2K near det. constraint on Flux × Xsec → SK samples (sub-GeV and CC quasi-elastic), T2K samples



Total minimum χ^2 goodness-of-fit (GOF) metric broken down into:

Individual experiment GOF metrics, mostly similar to existing studies by each experiment

"Parameter GOF" metrics* for consistency under PMNS oscillation and joint systematic uncertainty model. More powerful test of model sufficiency and independent of bin counts.

Good description of both data-sets.

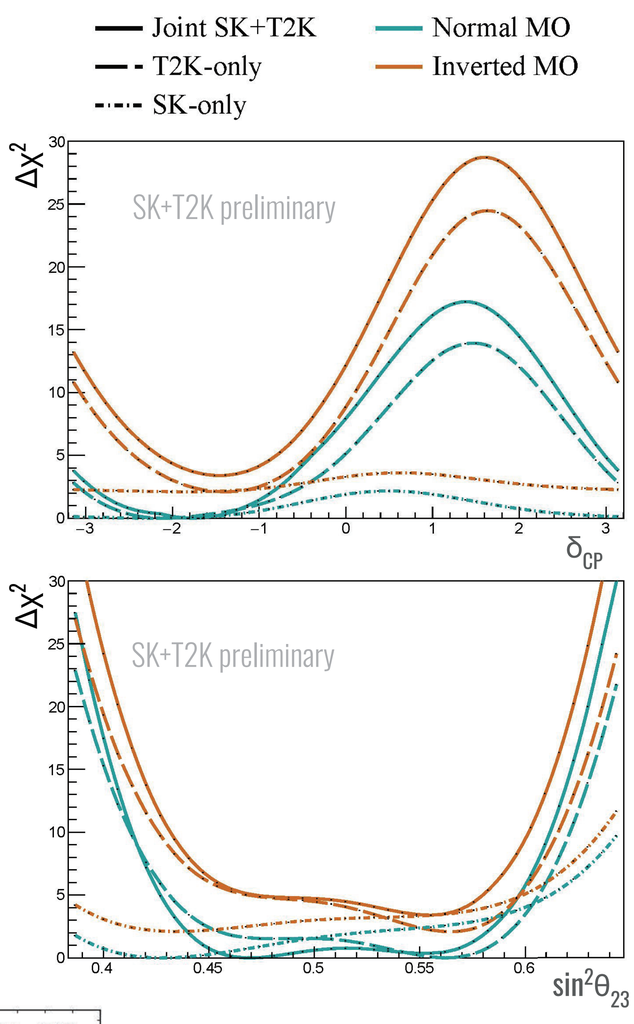
* Phys. Rev. D, 68:033020, 2003.

First data fit result

Data in this analysis:
Super-K IV (2008-2018)
T2K Run 1-10

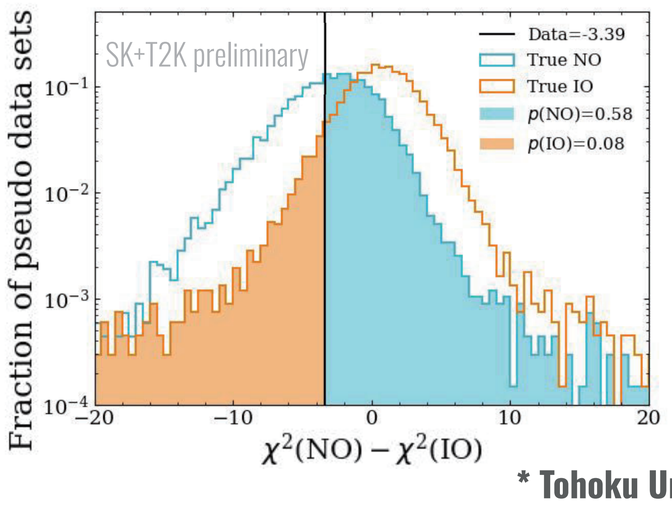
Both Super-K and T2K experiments prefer maximal CP-violation.

Enhanced CP-constraint in SK+T2K joint fit.



T2K-only data fit prefers upper octant, while the Super-K atmospheric only data fit shows a preference for the lower octant.

Joint SK+T2K does not have a strong octant preference

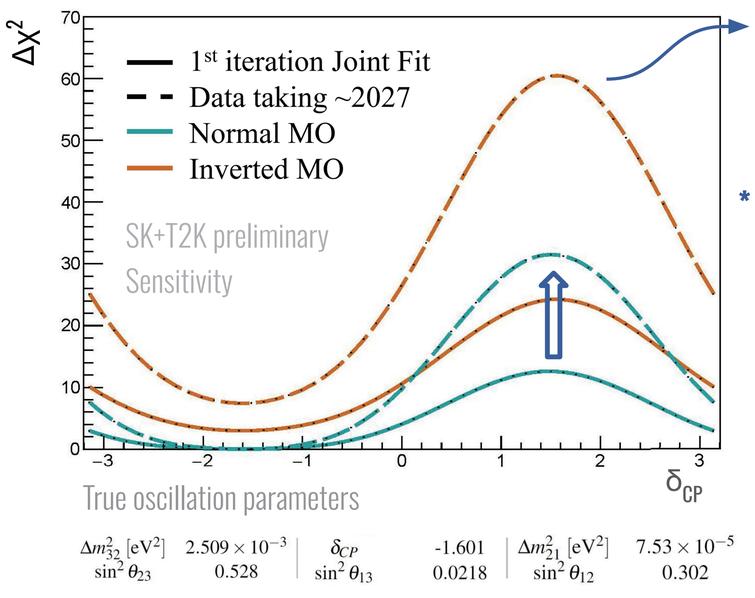


Weak preference for **normal mass ordering** with contribution from both experiments.

CL_s(IO) = 0.183

Joint fit reduces dependence on true δ_{CP} and $\sin^2\theta_{23}$.

Future sensitivity



Assume data taking will continue until the end of 2027

Include full Super-K data (2x), future SK+T2K* data

* SK: The number of calendar days with assumed detector livetime efficiency of 90%. T2K: The POT at the end of 2027 is ~10^{22}. Assume equal ratio of FHC and RHC.

Second iteration is now starting!

New samples and event selections in both experiments, latest interaction models, ...

Summary

Frequentist results from first joint SK+T2K data fit presented.
The conclusion is compatible with Bayesian results.

CP-conserving value of the Jarlskog invariant excluded with 1.9–2.0σ significance (depending on the analysis considered).

Weak preference for normal ordering.
No strong preference for the θ_{23} octant.

New CP-conservation test with improved frequentist properties.
Good consistency under correlated systematics model.

Next iteration of joint SK+T2K analysis starting with strong potential to improve the sensitivity.

arXiv / 2405.12488

Analysis model construction, frequentist and Bayesian results

* Tohoku University, lukasb@epx.phys.tohoku.ac.jp † King's College London, zhenxiong.xie@kcl.ac.uk