New results from Super-Kamiokande

Zhuojun Hu (ILANCE/Laboratoire Leprince-Ringuet, École polytechnique, CNRS)

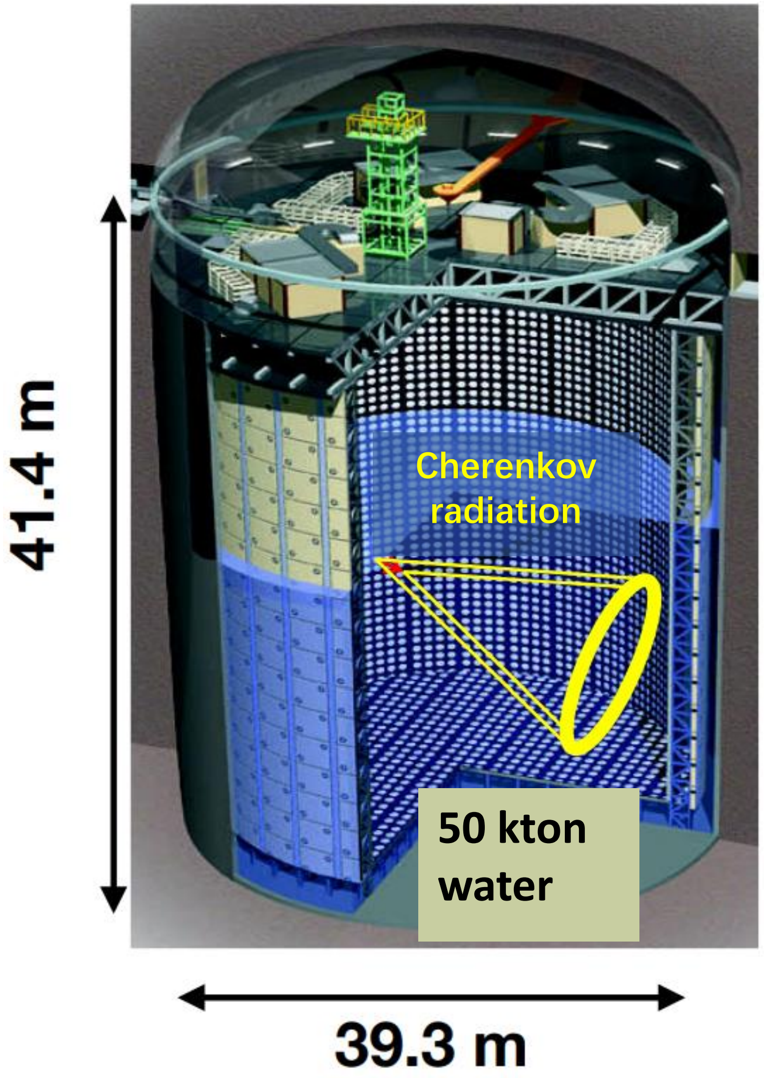
on behalf of the Super-Kamiokande collaboration

The XXXII International Conference on Neutrino Physics and Astrophysics (Neutrino 2026)

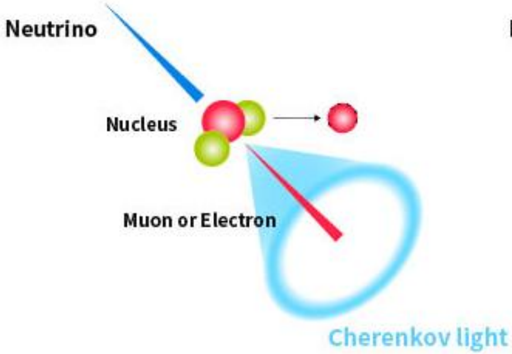
UC Irvine, CA, USA

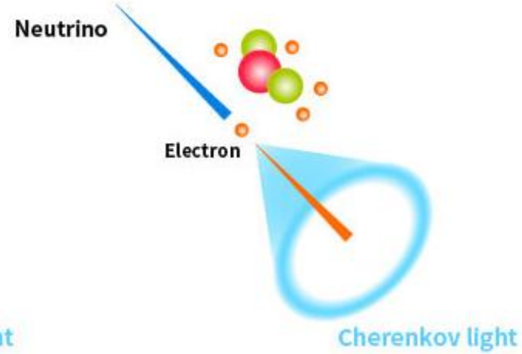
June 24, 2026

The Super-Kamiokande Detector



- Located at Kamioka, Gifu, Japan
- Under Mt. Ikenoyama (2,700 m.w.e)
- Inner detector watched by >11,000 20-inch PMTs
- Multi-purpose neutrino observatory
  - Solar neutrinos
  - Reactor neutrinos
  - Supernova neutrinos
  - Accelerator neutrinos
  - Atmospheric neutrinos

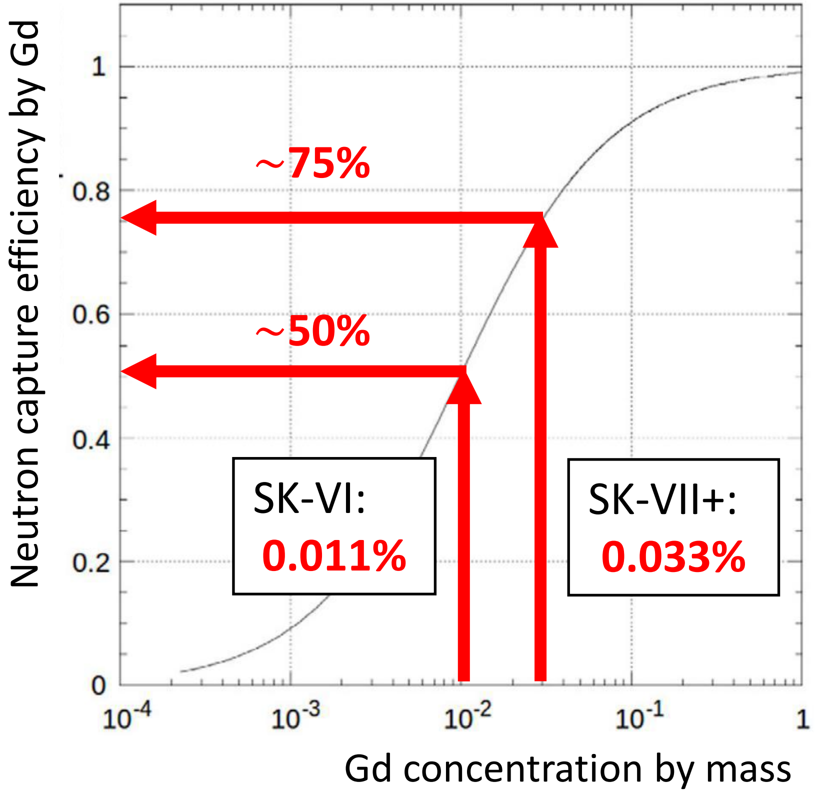




SK Data-taking Phases

30 years of continuous operation
- 5 pure water phases (6,511 live days)
- 3 SK-Gd phases (1,600+ live days)

SK-Gd era
- 1st loading finished in 2020: 0.011% Gd in water by mass
- 2nd loading finished in 2022: 0.033% Gd in water by mass



Pure water phase (livetime = 6,511 days)

SK-I | SK-II | SK-III | SK-IV | SK-V | SK-VI | SK-VII | SK-VIII

1996 2002 2006 2008 2018 2019 2020 2022 2024 2026

The Super-Kamiokande Collaboration

~250 collaborators
from 59 institutes
in 11 countries

30th ANNIVERSARY Happy birthday!

Kamioka Observatory, ICRR, Univ. of Tokyo, Japan
RCCN, ICRR, Univ. of Tokyo, Japan
University Autonoma Madrid, Spain
BC Institute of Technology, Canada
Boston University, USA
BMCC/CUNY, USA
University of California, Irvine, USA
California State University, USA
University of Chinese Academy of Sciences, China
Chonnam National University, Korea
Duke University, USA
Gifu University, Japan
GIST, Korea
University of Glasgow, UK
University of Hawaii, USA
Hiroshima University, Japan
IBS, Korea
IFIRSE, Vietnam
Imperial College London, UK
ILANCE, France/Japan
INFN Bari, Italyl
INFN Napoli, Italy
INFN Padova, Italy
INFN Roma, Italy
Institute of Science Tokyo, Japan
Kavli IPMU, The Univ. of Tokyo, Japan
Keio University, Japan
KEK, Japan
King's College London, UK
Kobe University, Japan
Kyoto University, Japan
Kyungpook National University, Korea
University of Liverpool, UK
LLR, Ecole polytechnique, France
University of Minnesota, USA
Miyagi University of Education, Japan
ISEE, Nagoya University, Japan
NCBJ, Poland
NIT, Nihama college, Japan
NIT, Numazu college, Japan
Okayama University, Japan
Osaka Electro-Communication Univ.,Japan
University of Oxford, UK
Rutherford Appleton Laboratory, UK
Seoul National University, Korea
University of Sheffield, UK
Shizuoka University of Welfare, Japan
University of Silesia in Katowice, Poland
Sungkyunkwan University, Korea
Tohoku University, Japan
The University of Tokyo, Japan
Tokyo University of Science, Japan
University of Toyama, Japan
TRIUMF, Canada
Tsinghua University, China
University of Warsaw, Poland
Warwick University, UK
The University of Winnipeg, Canada
Yokohama National University, Japan

New Results from SK

This talk

- **Atmospheric neutrino measurements**
  - **zenith angle oscillation analysis**
  - **L/E oscillation analysis**
  - **unitarity violation search**

- **Solar neutrino measurements**
  - **solar core size and temperature**
  - **hep neutrino search**

- **Reactor neutrino measurements**
  - **spectrum and oscillation**

Other presentations at Neutrino 2026

- **Supernova Neutrinos in Super-Kamiokande**
  [Talk by Hiroyuki Sekiya, Thursday 11:30 am]

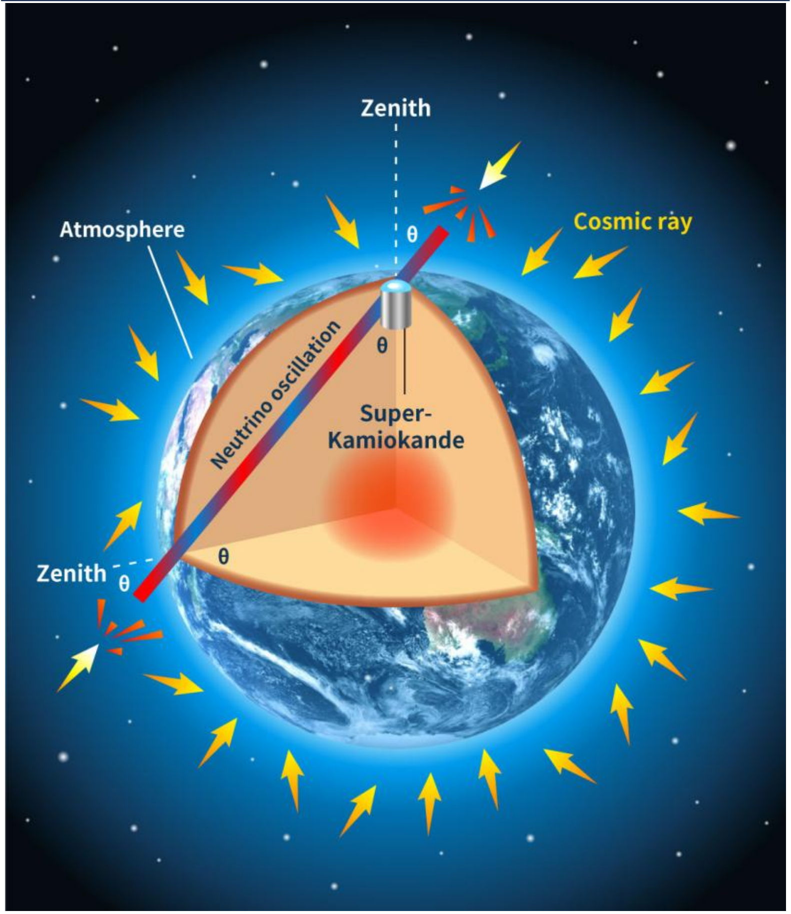
[Posters]

- Neutron capture simulation [Yota Hino, #38]
- Supernova neutrino monitor [Guillaume Pronost, #84]
- Solar *hep* neutrinos [Yiyang Wu, #90]
- Neutron tagging study [Mao Nishigami, #102]
- K/π ratio measurement [Tomoaki Tada, #217]
- Atmospheric neutrino oscillation [Ben Jargowsky, #225]
- M31-2014-DS1 coincident neutrinos [Fumi Nakanishi, #228]
- Atmospheric L/E analysis [Mariusz Girgus, #230]
- KM3-230213A coincident neutrinos [Xubin Wang, #333]
- Spallation background for DSNB [Masayuki Harada, #342]
- Sterile neutrino search [Yushi Yoshioka, #355]
- New results from DSNB search [Saki Fujita, #360]
- Muon study at KamLAND and SK [Keita Saito, #415]
- DSNB search with neural network [Bin Zhang, #424]
- NCQE background in DSNB [Licheng Feng, #502]
- Solar core size and temperature [Yifan Jiang, #573]

Atmospheric Neutrinos

Atmospheric Neutrinos

$$\pi^{\pm}(K^{\pm}) \rightarrow \mu^{\pm} + \nu_{\mu}(\bar{\nu}_{\mu})$$
$$\searrow e^{\pm} + \bar{\nu}_{\mu}(\nu_{\mu}) + \nu_{e}(\bar{\nu}_{e})$$



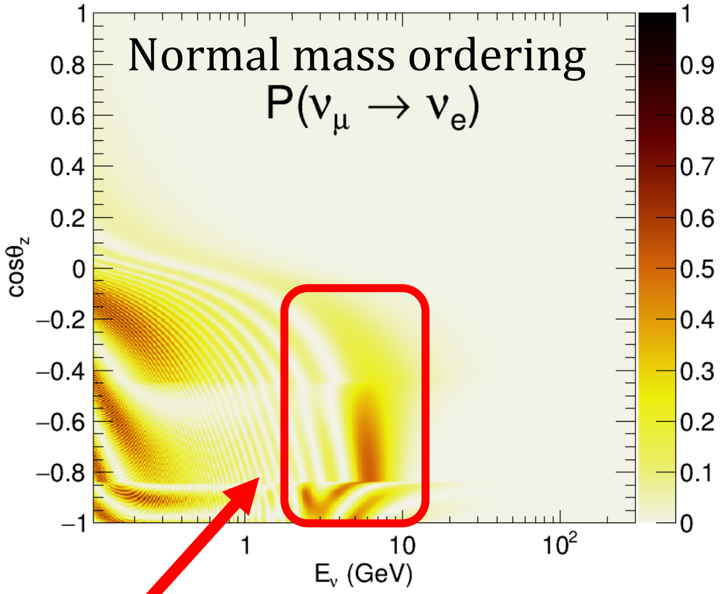
From cosmic-ray interactions in atmosphere

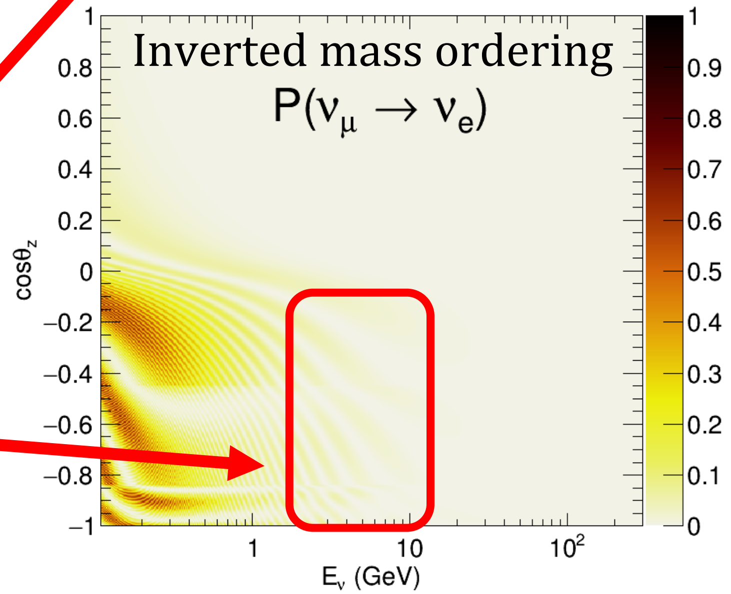
- Baseline: 10 km - 13,000 km
- Energy: MeV - TeV

Detected via charged-current interactions

Oscillation measurements:

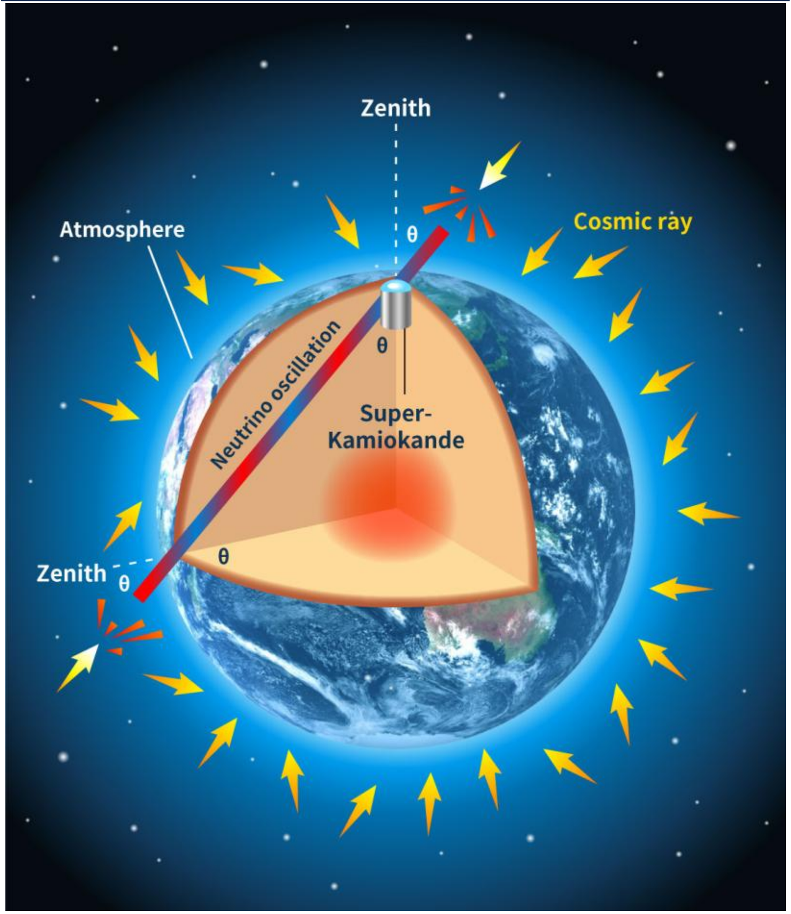
- ν_{μ} disappearance
  - Δm^2_{32}
  - $\sin^2\theta_{23}$
- ν_e appearance
  - Mass-ordering
  - CP phase δ





Atmospheric Neutrinos

$$\pi^{\pm}(K^{\pm}) \rightarrow \mu^{\pm} + \nu_{\mu}(\bar{\nu}_{\mu})$$
$$\mu^{\pm} \rightarrow e^{\pm} + \bar{\nu}_{\mu}(\nu_{\mu}) + \nu_{e}(\bar{\nu}_{e})$$



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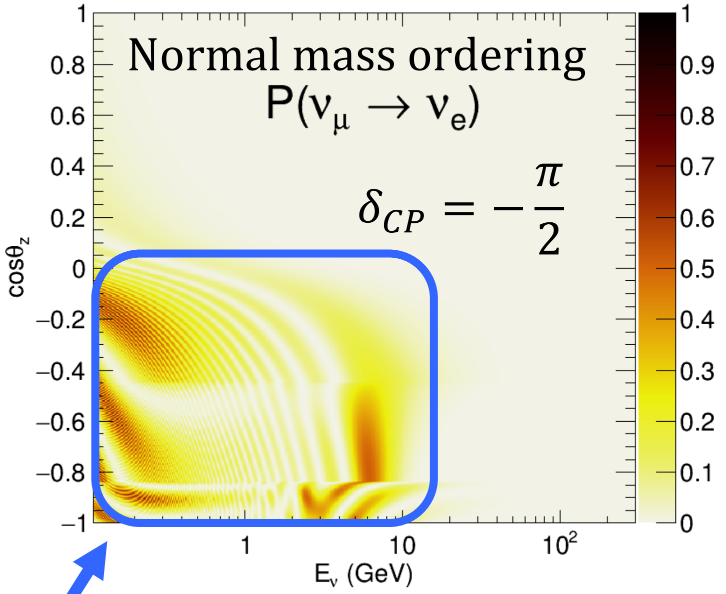
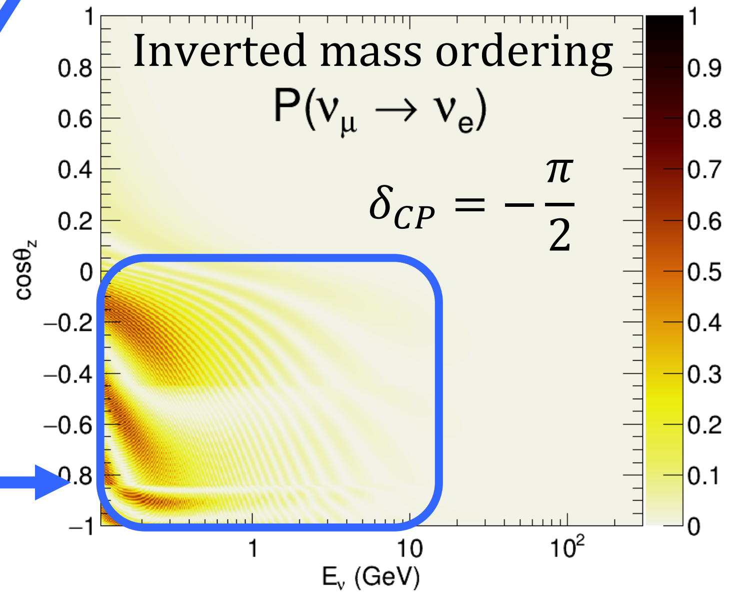
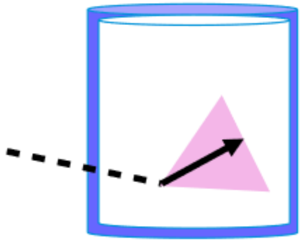




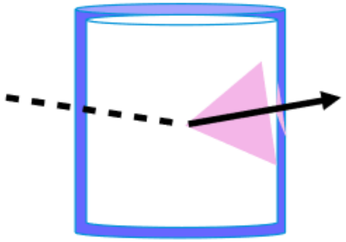
Zenith Angle-based Oscillation Measurement

Poster by Ben Jargowsky, #225

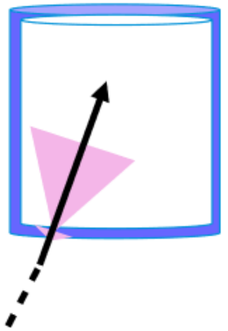
Fully Contained (FC)

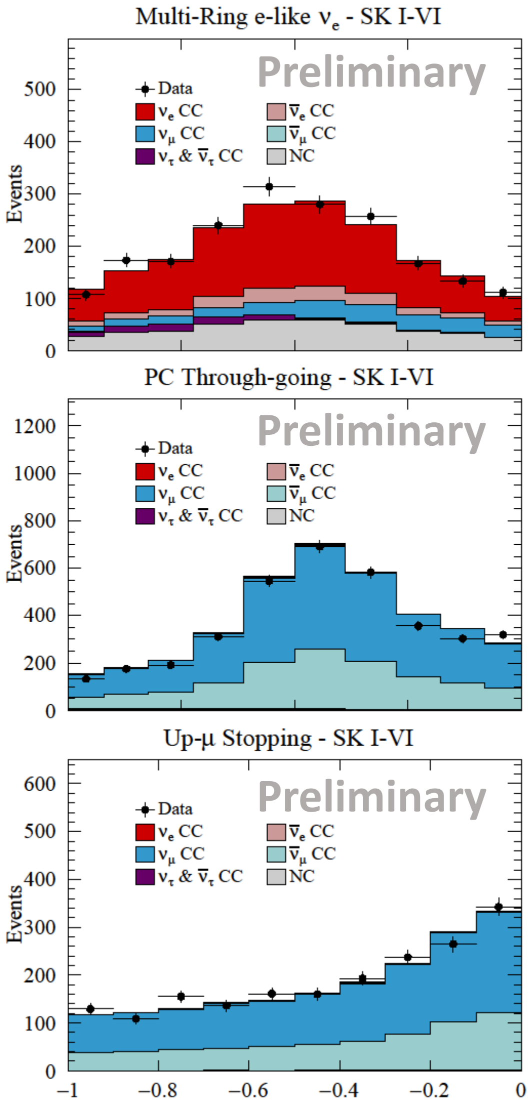


Partially Contained (PC)



Upward-going Muons (Up-μ)





cosine zenith angle

Zenith Angle-based Oscillation Measurement

Poster by Ben Jargowsky, #225

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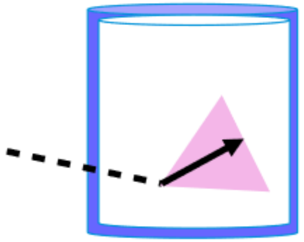
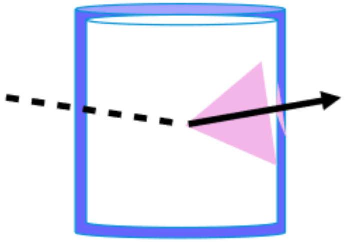
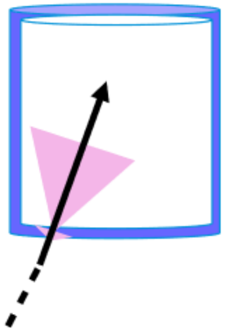
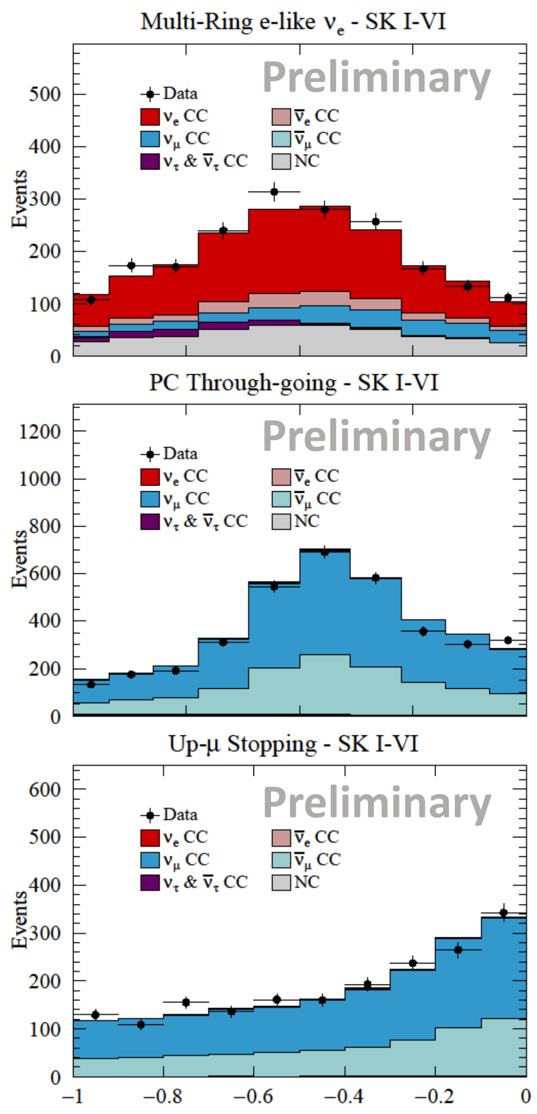


Partially Contained (PC)



Upward-going Muons (Up-μ)





cosine zenith angle

SK I-VI:

Total exposure: 526.9 kton-years

(7,075.7 days × 27.2 kton)

- Full pure water + SK VI (0.011% Gd in weight)
- data binned into samples enhanced in different interactions processes

What's new in this measurement?

- the addition of SK VI data (+8.8% stat.)
- new MC with updated neutrino event generator
- new neutron-based reconstruction for Gd phase (SK VI)
- improved BDT-based multi-ring event classifier
- ν_τ constraint on multi-GeV ν_e-enhanced samples

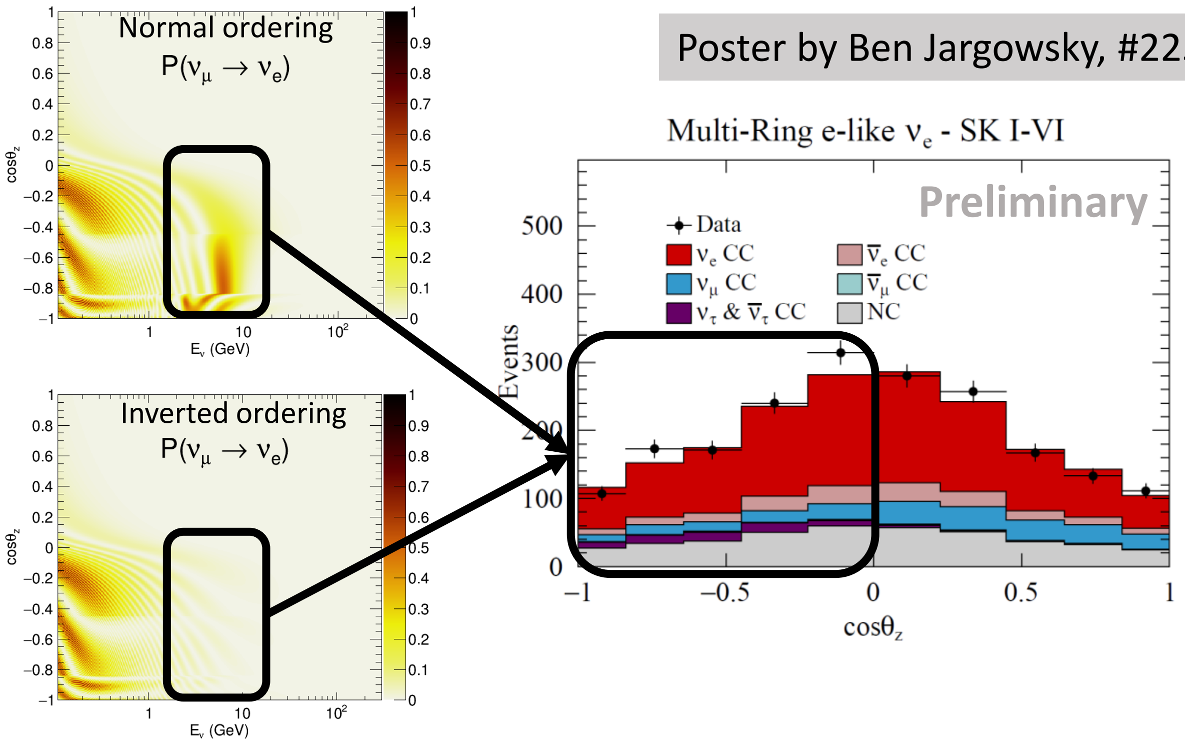
Efforts towards better $\nu_e/\bar{\nu}_e$ separation, vital for determination of mass ordering

ν_τ constraint

Key information of **mass ordering** comes from the upward-going Multi-GeV e-like samples

- ν_τ contaminates the same regions

Poster by Ben Jargowsky, #225



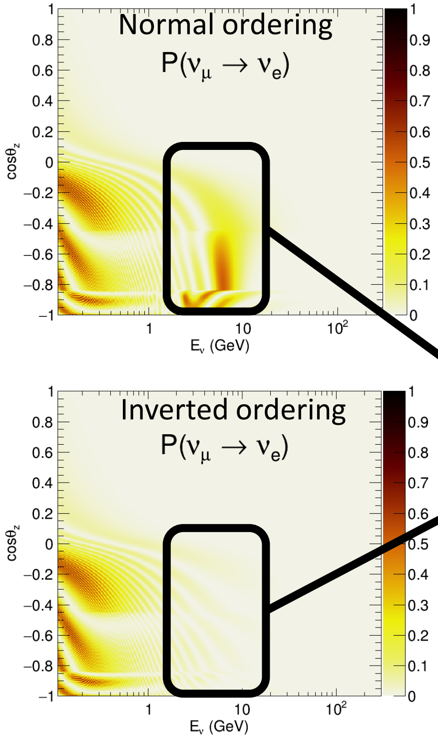
ν_τ constraint

Key information of **mass ordering** comes from the upward-going Multi-GeV e-like samples

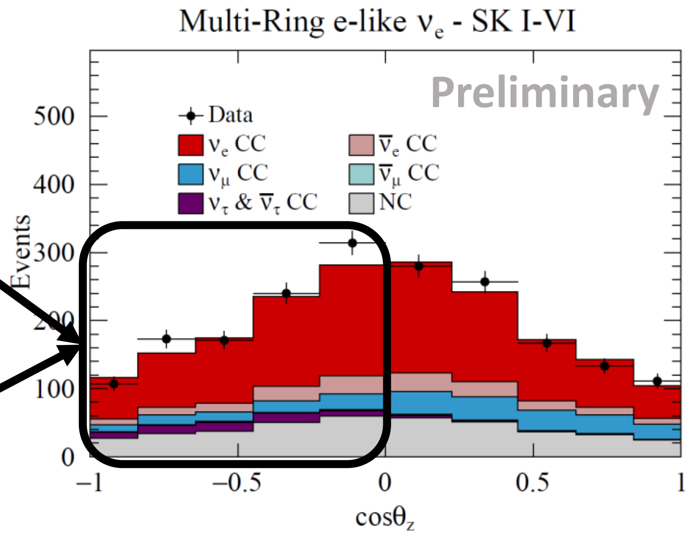
- ν_τ contaminates the same regions

Improved ν_τ identification with a simple NN

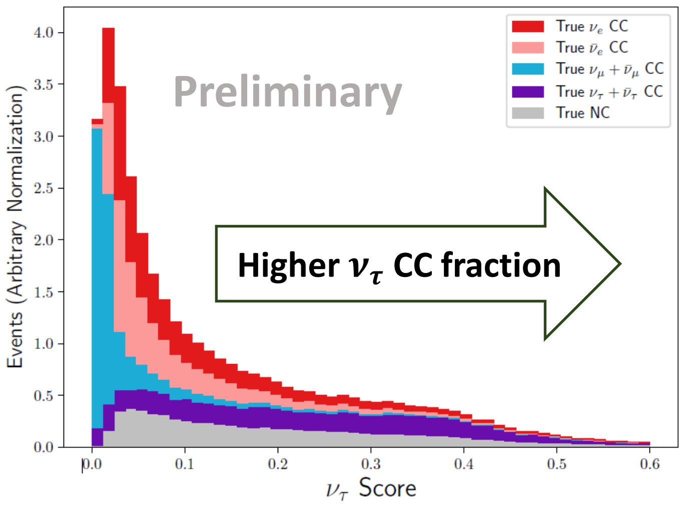
- split each multi-GeV e-like sample into high or low ν_τ contamination samples
- **~10% improvement to mass ordering sensitivity**

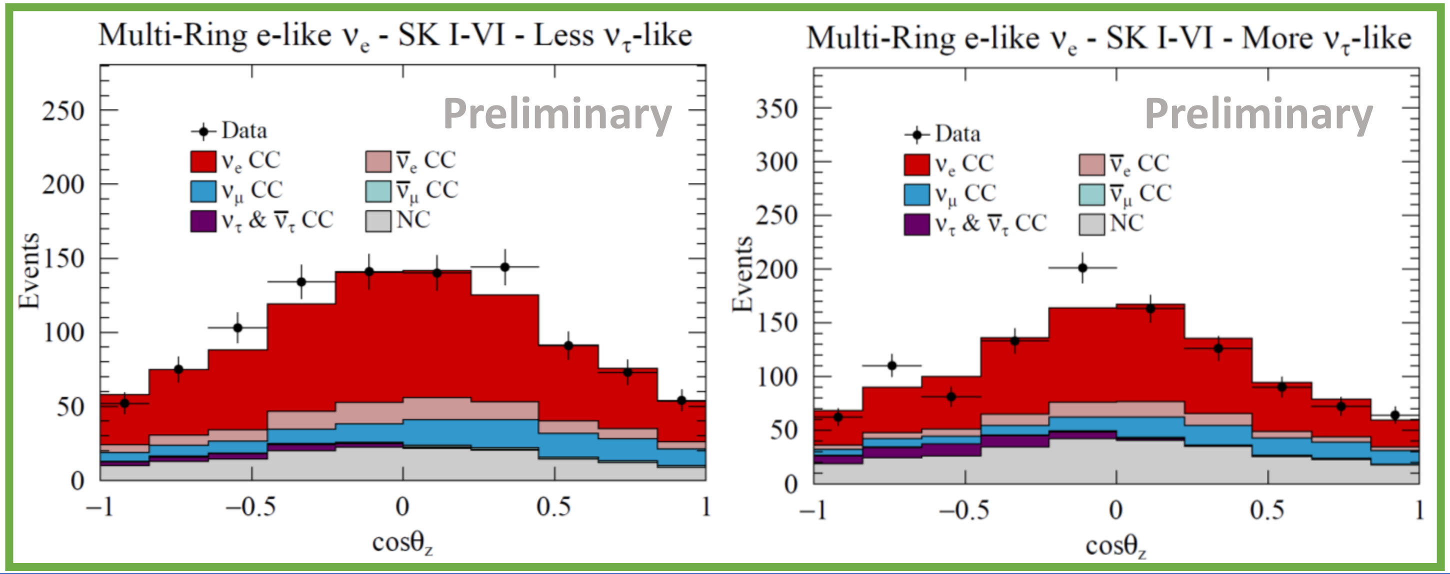


Poster by Ben Jargowsky, #225



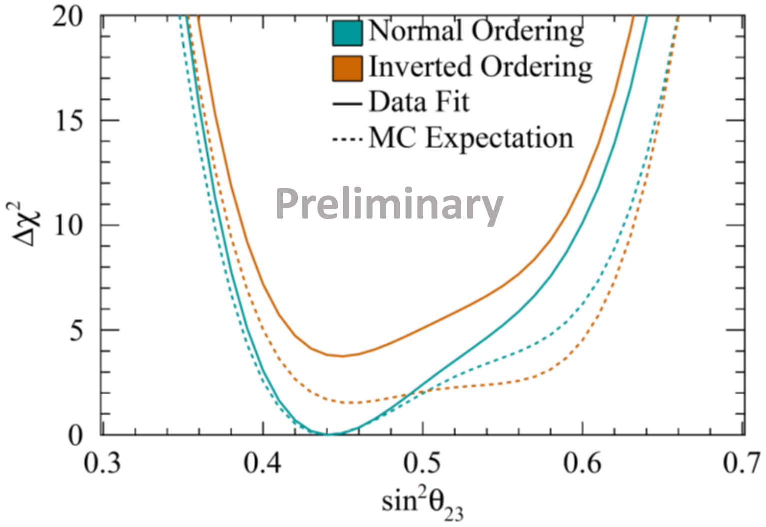
split

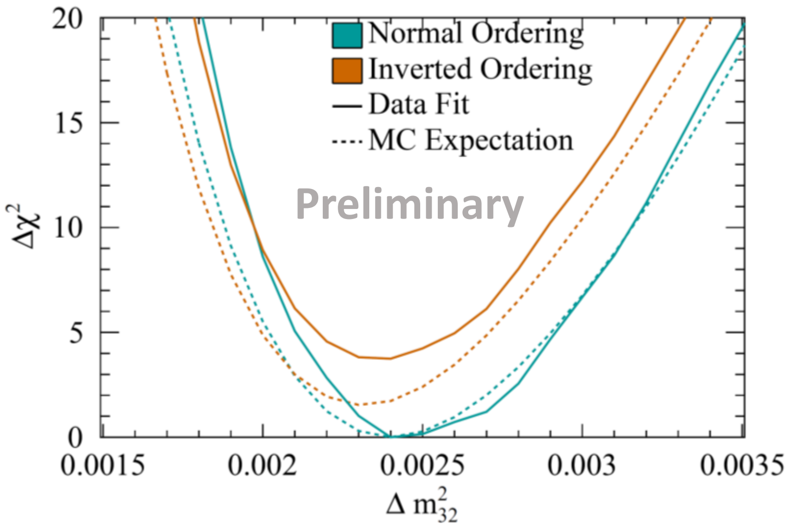


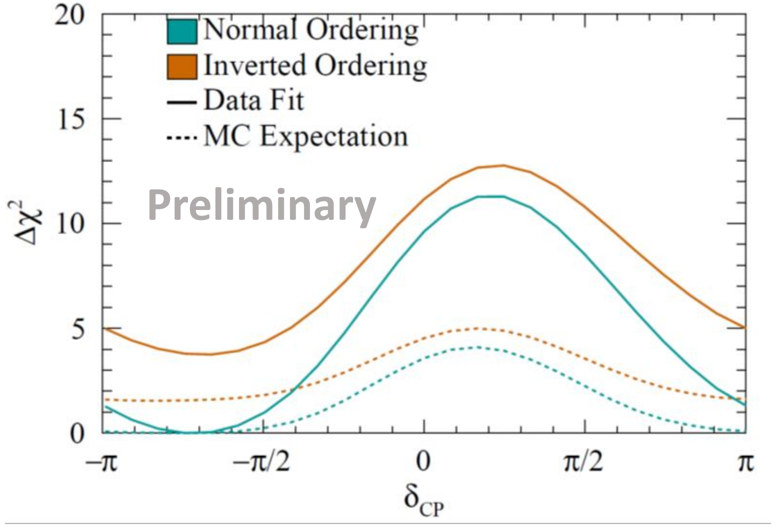


SK I-VI Oscillation Parameter Measurement

Poster by Ben Jargowsky, #225





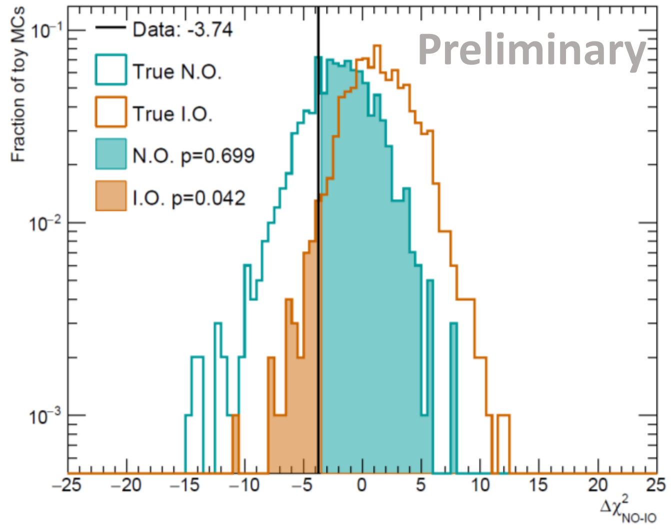


	Previous study (SK I-V)	This study (SK I-VI)
$\sin^2\theta_{23}$	0.45	**0.44**
Δm^2_{32} $[10^{-3}$ eV$^2]$	2.40	**2.40**
δ_{CP}	$-\pi/2$	**$-3\pi/4$**
$\Delta\chi^2_{IO-NO}$	5.69	**3.69**

*$\sin^2\theta_{13}$ prior: 0.0220 ± 0.0007
**Results of MO and δ_{CP} exceed sensitivity

- Favors lower octant at $\sim 1\sigma$
- Smaller $\sin^2\theta_{32}$ results in less sensitivity to mass ordering
- Roughly same δ_{CP} allowed region
- Favors normal ordering

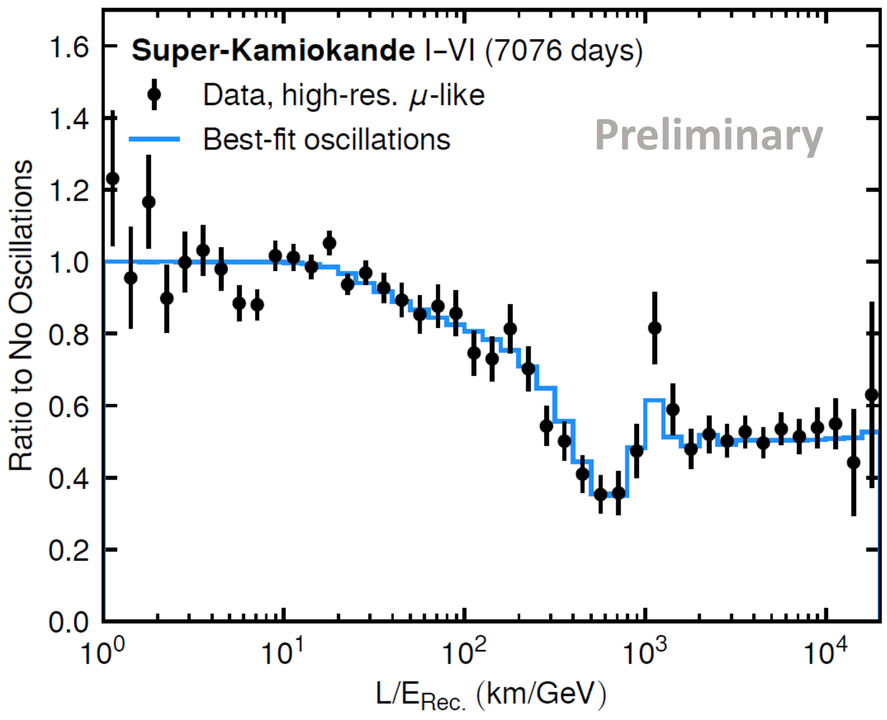
Toy experiments show a rejection of inverted ordering at 86% ≃ 1.08σ (CL_s method)

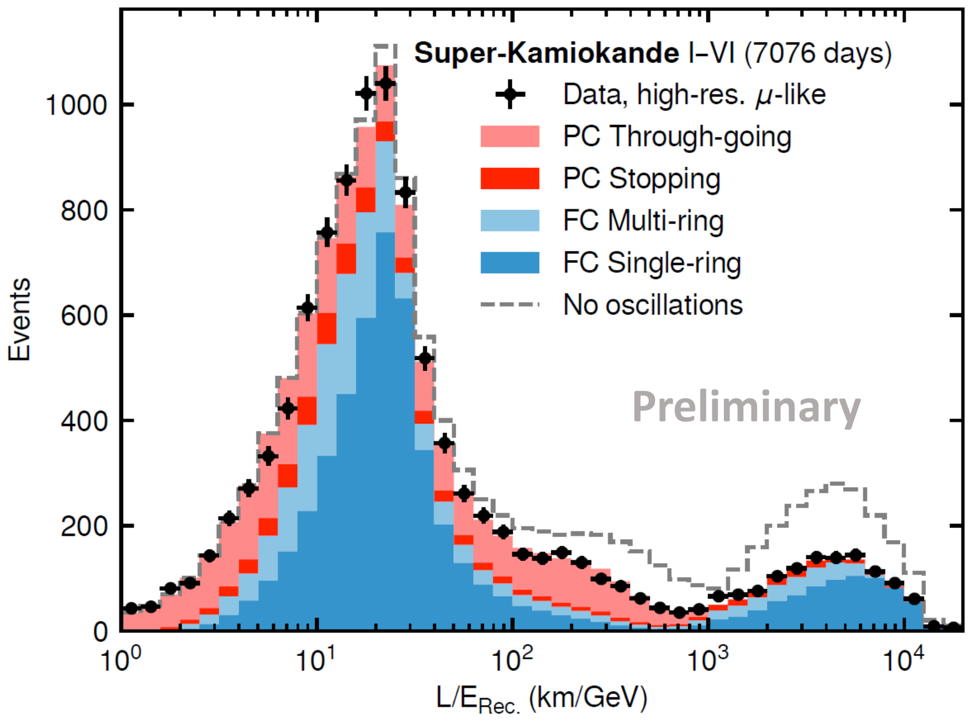


L/E Analysis at SK

Poster by Mariusz Girgus, #230

Prob $\nu_\mu \rightarrow \nu_\mu$ oscillations across >4 orders of magnitude in L/E
- using SK I-VI data, but μ-like samples only
- cover the 1st osc. minimum and the 2nd osc. maximum





L/E resolution: variation of true L/E at given reconstructed L/E
- high resolution sample: reconstructed L/E scheme
- low resolution sample:
  - zenith angle and lepton momentum scheme,
  - constrain systematics.

L/E Oscillation Measurement

Poster by Mariusz Girgus, #230

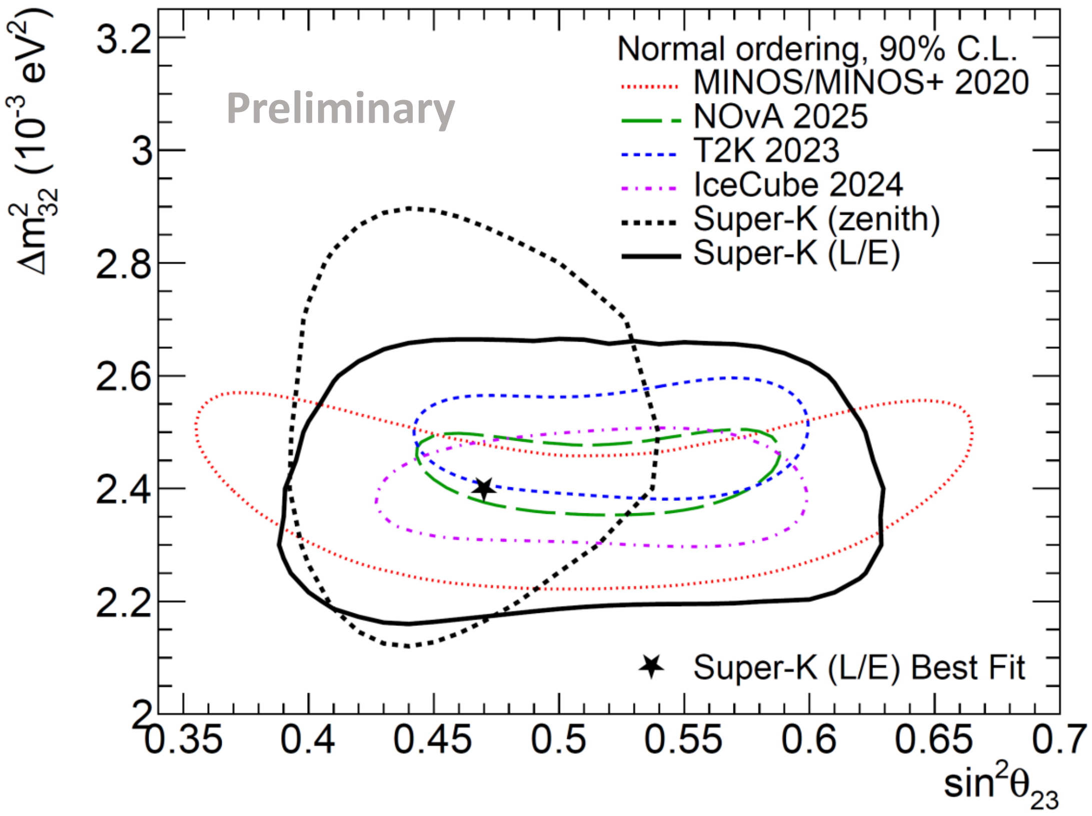
Update from 2024 results:

- Introduced a new BDT classifier to separate partially contained (PC) stopping/through-going events
- Increased high resolution PC events by 10% in the oscillation region ($(L/E)_{\mathrm{rec}} > 100\ \mathrm{km/GeV}$)

L/E analysis sets a stronger constraint on Δm^2_{32}

- high resolution sample preserves the oscillatory pattern that would otherwise be averaged out in zenith-angle analysis
- lose power to determine θ_{23} octant because ν_e samples are not included

Prospect: implement L/E in standard oscillation analysis



L/E data fit contour assuming NO, in comparison with zenith angle data fit, and other experimental results

Non-Unitarity Analysis

$$\begin{pmatrix} |U_{e1}| & |U_{e2}| & |U_{e3}| \\ |U_{\mu1}|e^{i\delta_{\mu1}} & |U_{\mu2}|e^{i\delta_{\mu2}} & |U_{\mu3}| \\ |U_{\tau1}|e^{i\delta_{\tau1}} & |U_{\tau2}|e^{i\delta_{\tau2}} & |U_{\tau3}| \end{pmatrix} \quad \begin{matrix} \Delta m^2_{21} \\ \Delta m^2_{32} \end{matrix}$$

(red): external priors from solar/reactor ν

(blue): flat priors

Unitarity violation induced by heavy sterile neutrinos

- Δm^2 too large to oscillate

Expand neutrino mixing matrix

- Unitary: 3 mixing angle + 1 CP phase
- Non-unitary: 9 magnitudes + 4 phases

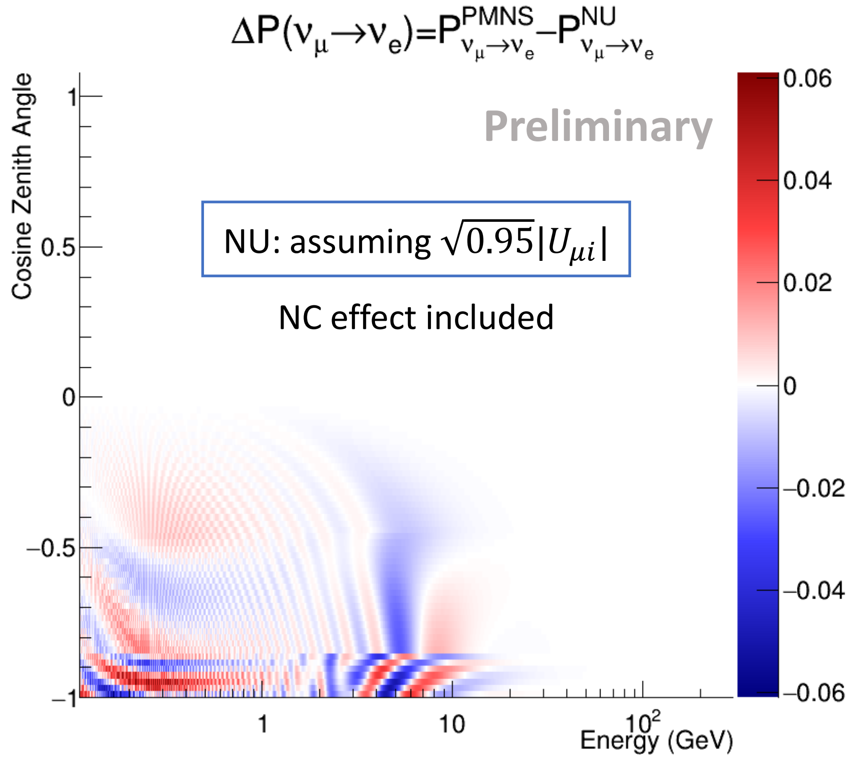
Measured neutrino mixing matrix w/o imposing unitarity constraints

- SK I-V data, 6,511 days
- Bayesian analysis using MCMC

Preliminary results in Generic Unitarity Violation (GUV)

- No restriction on normalizations and closures

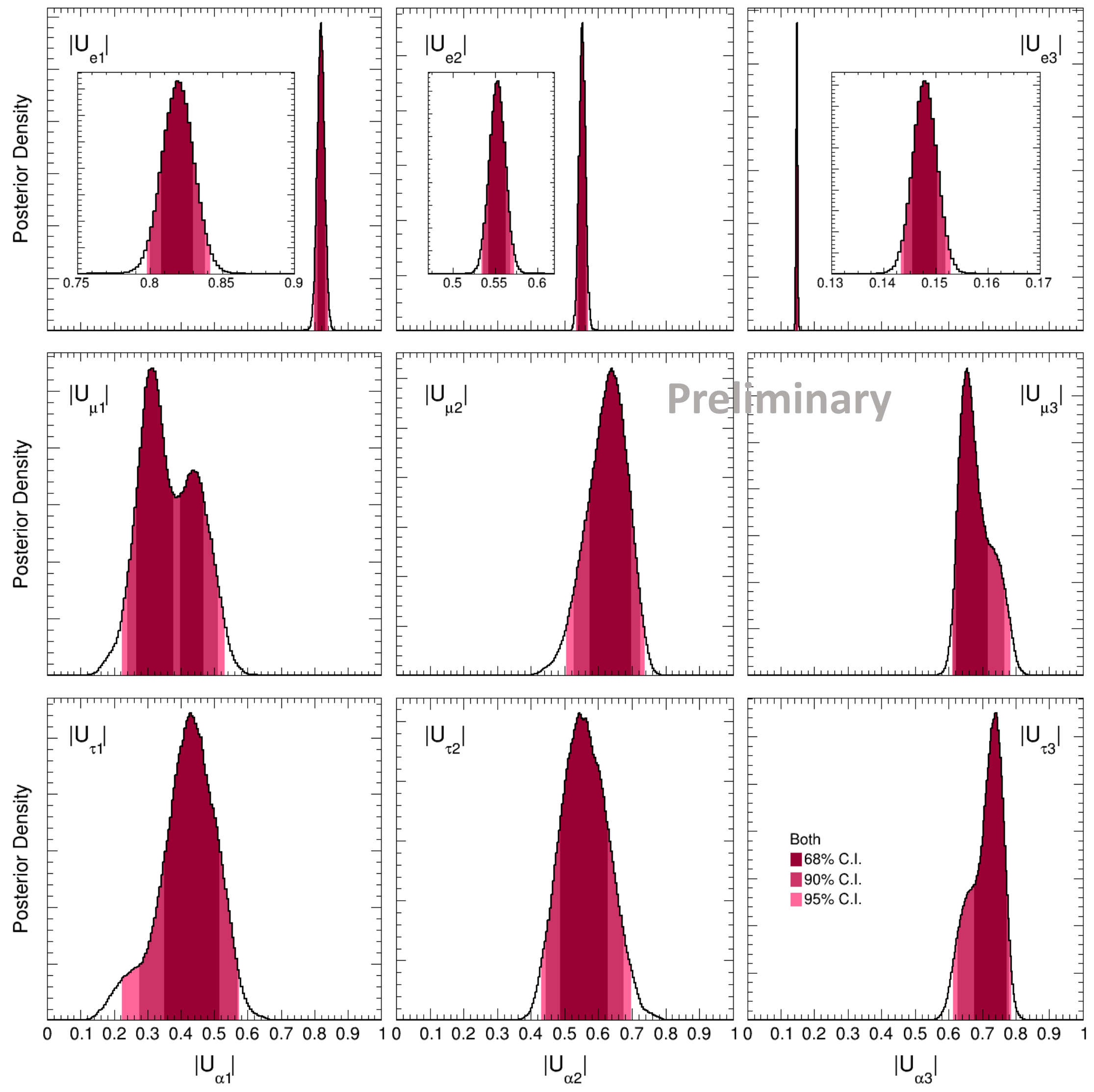
*Minimal Unitarity Violation (MUV): normalizations not exceed 1; closures follow Cauchy-Schwarz inequality.



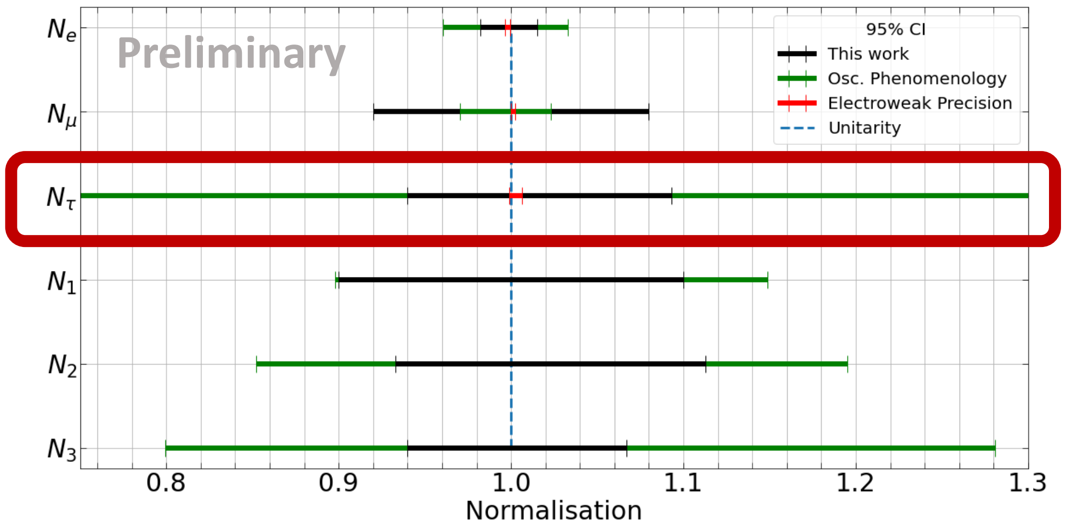
S. Parke, M. Ross-Lonergan, Phys.Rev.D 93 (2016) 11, 113009

Non-Unitarity Analysis Results

Green: *S.A.R. Ellis, et al., JHEP 12 (2020) 068*
Red: *M. Blennow, et al., JHEP 08 (2023) 030*



9 magnitudes



- Posteriors of matrix elements in GUV are in agreement with unitary results.
- Tested all unitarity conditions, all agree with unitary.
- Highly competitive limits, with outstanding result on the τ-row.

Solar Neutrinos

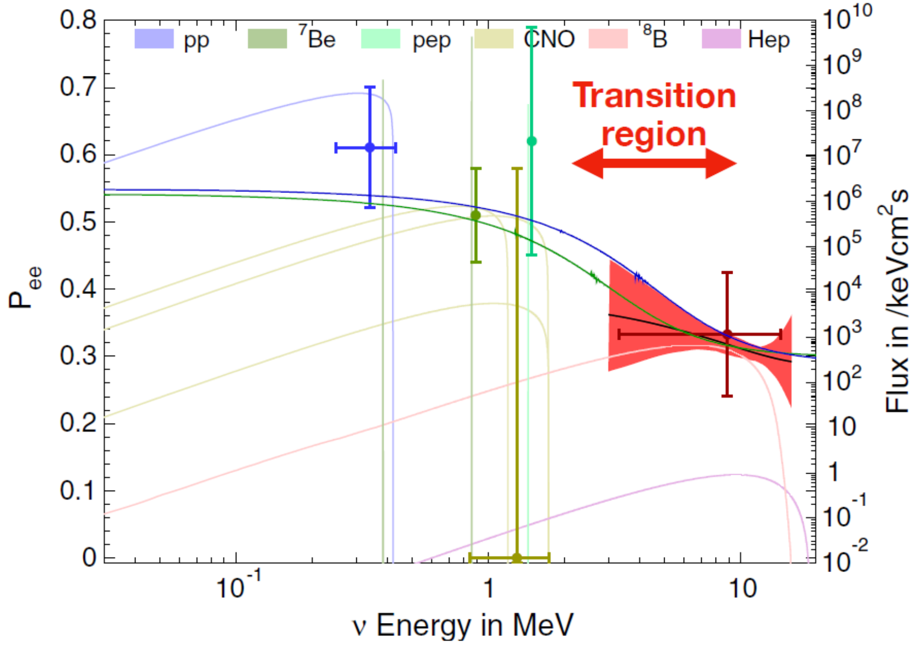
Solar Neutrinos

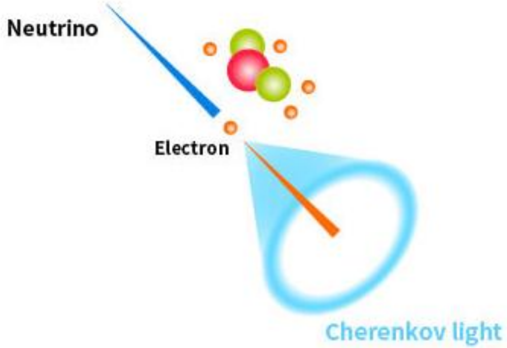
Intensely generated in the Sun's core from nuclear interactions

SK detects ^{8}B (and hep) solar ν via elastic scatterings

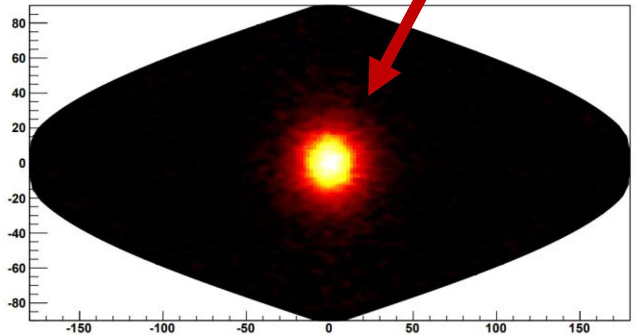
- huge statistics and precise energy determination
- find solar direction
- monitor time variation

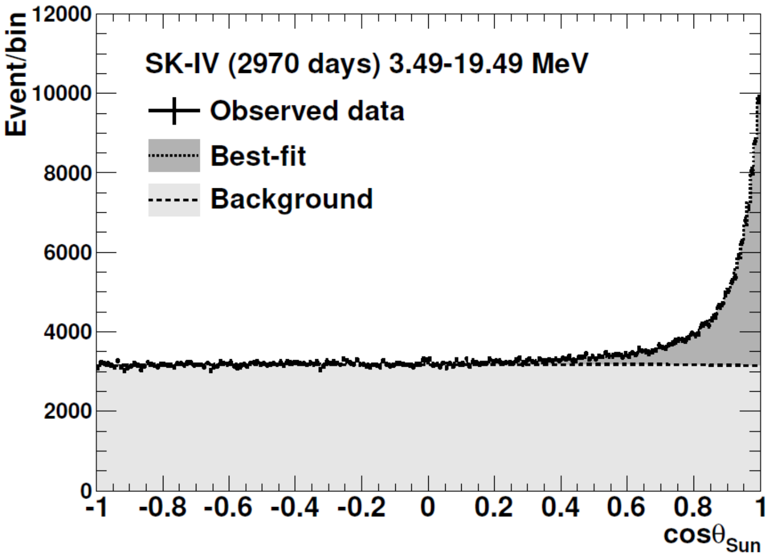
Key measurements
- ^{8}B solar neutrino flux & oscillation
- day/night asymmetry
- solar core size & temperature
- *hep* neutrino search





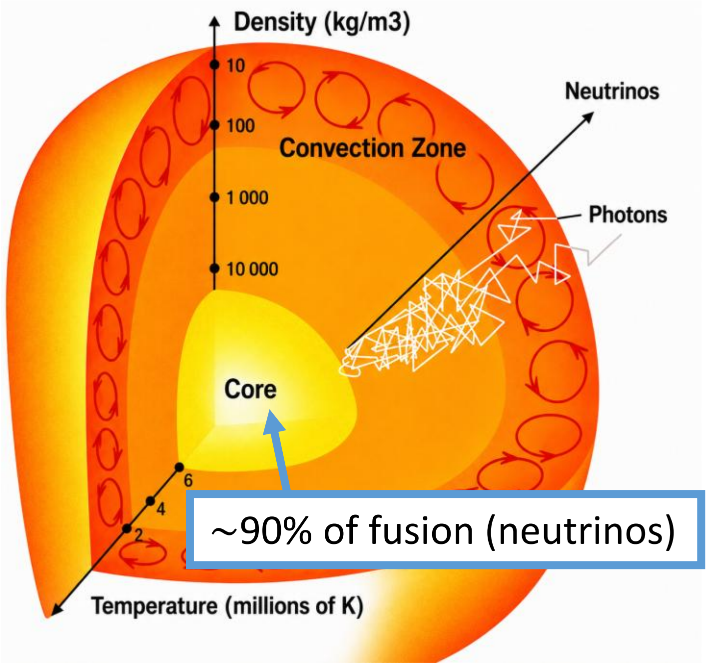
see the Sun via ν





Looking into Solar Core

Poster by Yifan Jiang, #573



Defined as where most of the fusions occur

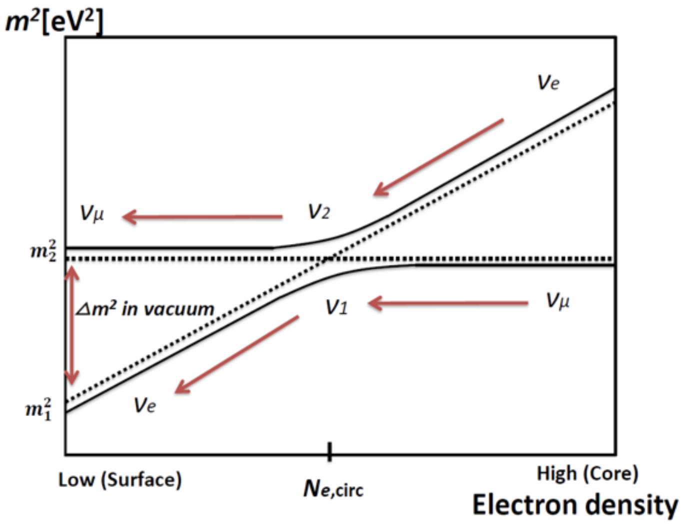
- no direct probe via photons
- neutrinos: a unique probe

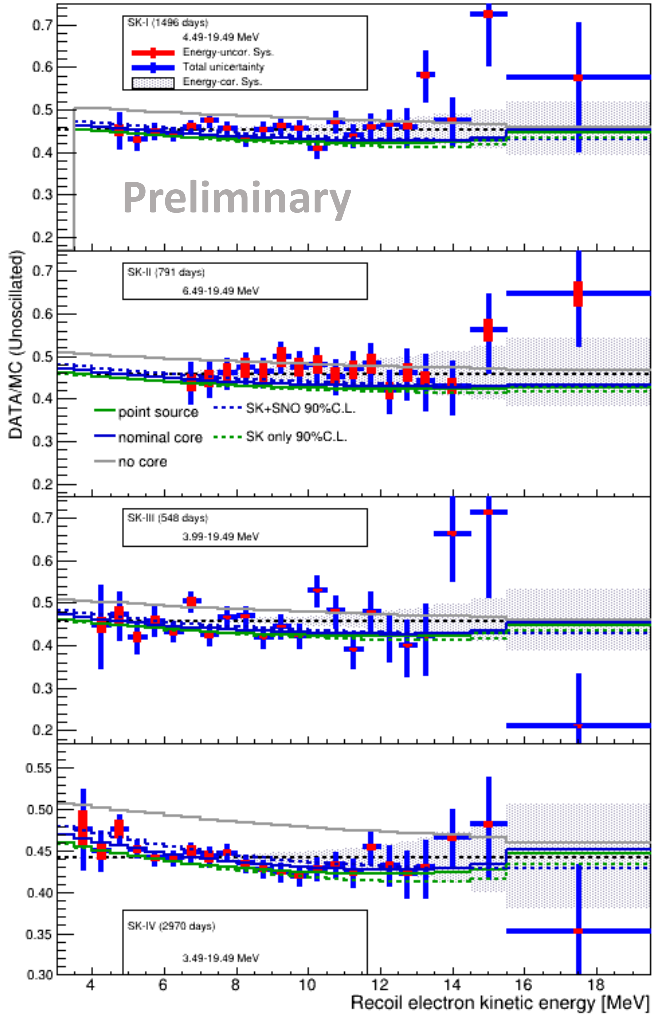
$$^{8}\mathrm{B} \rightarrow {}^{8}\mathrm{Be}^{*} + e^{+} + \nu_e$$

  - can travel unimpeded to Earth

Determination of solar core size

- electron density falls roughly exponentially with radius, and controls the onset of the adiabatic conversion ($\nu_e \rightarrow \nu_2$)
- different neutrino production radii lead to different P_{ee}
- ^{8}B neutrino spectra → solar core size





SK I-IV: 5695 live days

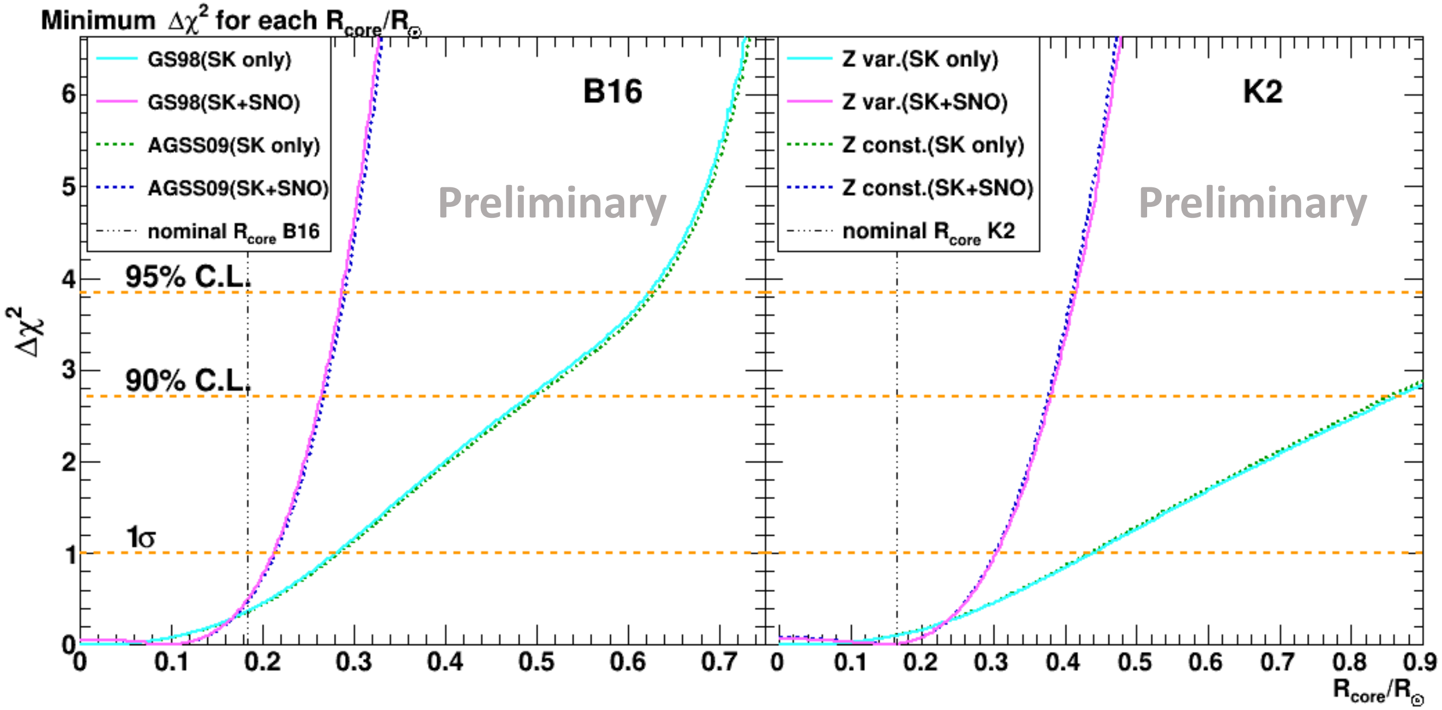
SK I-IV Solar Core Size

Poster by Yifan Jiang, #573

Solar models

Standard (B16): based on stellar evolution
- GS98: high metallicity (favored)
- AGSS09: low metallicity

Non-standard (K2): low metallicity but reconciled with helioseismology
- K2-MZvarA2-12: time-dependent accretion metallicity Z (favored)
- K2-A2-12: constant metallicity Z



Data fit:
- Vary ^{8}B neutrino production profile and electron density from each solar model
- Oscillation parameter constraints from JUNO
- Fit against ^{8}B neutrino spectrum

90% C.L. upper limit for solar core size (SK+SNO)
- 0.268 $R_\odot$ for **B16**, assuming high metallicity
- 0.381 $R_\odot$ for **K2**, assuming Z variable

Exclude the scenario with no solar core at >99% C.L.
- **B16** using only SK data
- **both B16 and K2**, SK+SNO fit

SK I-IV Solar Core Temperature

Poster by Yifan Jiang, #573

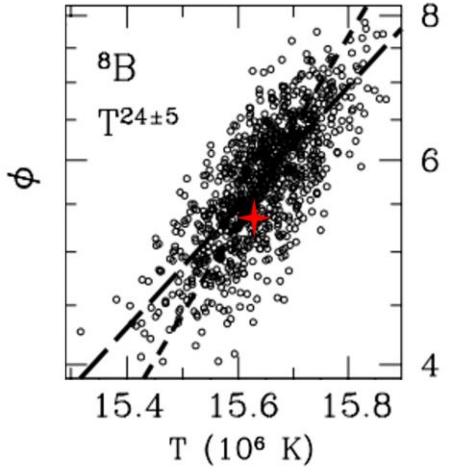
$^3\mathrm{He} + {}^4\mathrm{He} \rightarrow {}^7\mathrm{Be} + \gamma$

$^7\mathrm{Be} + \mathrm{p} \rightarrow {}^8\mathrm{B} + \gamma$

temperature sensitive

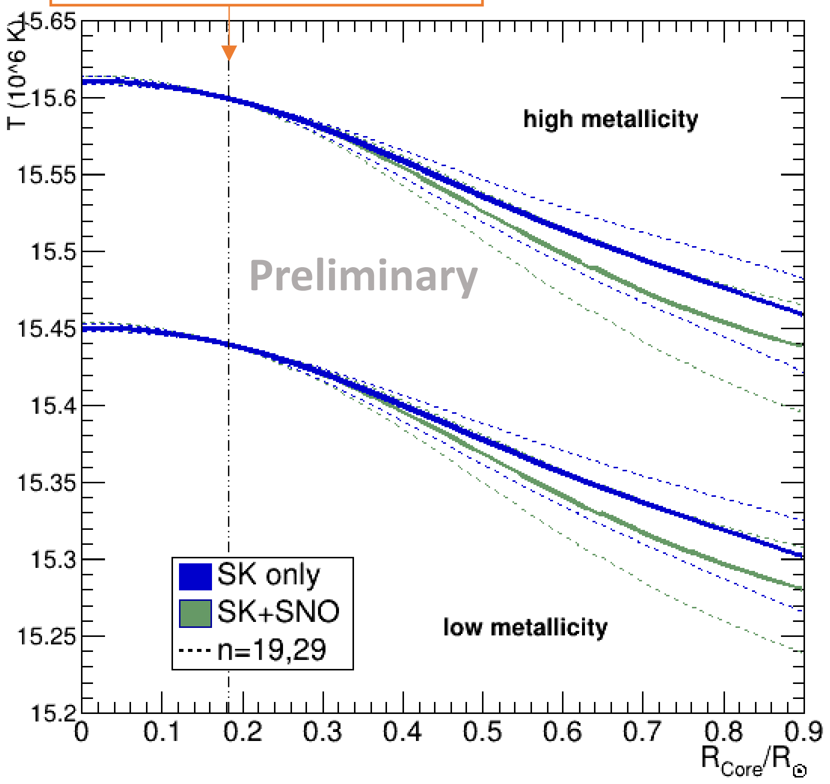
$^8\mathrm{B} \rightarrow {}^8\mathrm{Be}^* + e^+ + \nu_e$

Core temperature: $T_C \propto \Phi_{^8\mathrm{B}}{}^{24\pm5}$



J.N.Bahcall, A.Ulmer, PRD 53 (1996), pp. 4202–4210

B16 nominal core size



Assuming SSM(B16) nominal core size, $T_C \propto \Phi_{^8\mathrm{B}}{}^{24}$

- high metallicity $T_c = \left(15.599^{+0.0015}_{-0.0016}\right) \times 10^6$ K
- low metallicity $T_c = (15.441^{+0.0017}_{-0.0018}) \times 10^6$ K

First measurement of solar core temperature

hep Neutrinos

Poster by Yiyang Wu, #90

***hep* neutrinos:** $^{3}\mathbf{He} + \mathbf{p} \rightarrow {}^{4}\mathbf{He} + \boldsymbol{e}^{+} + \boldsymbol{\nu_e}$

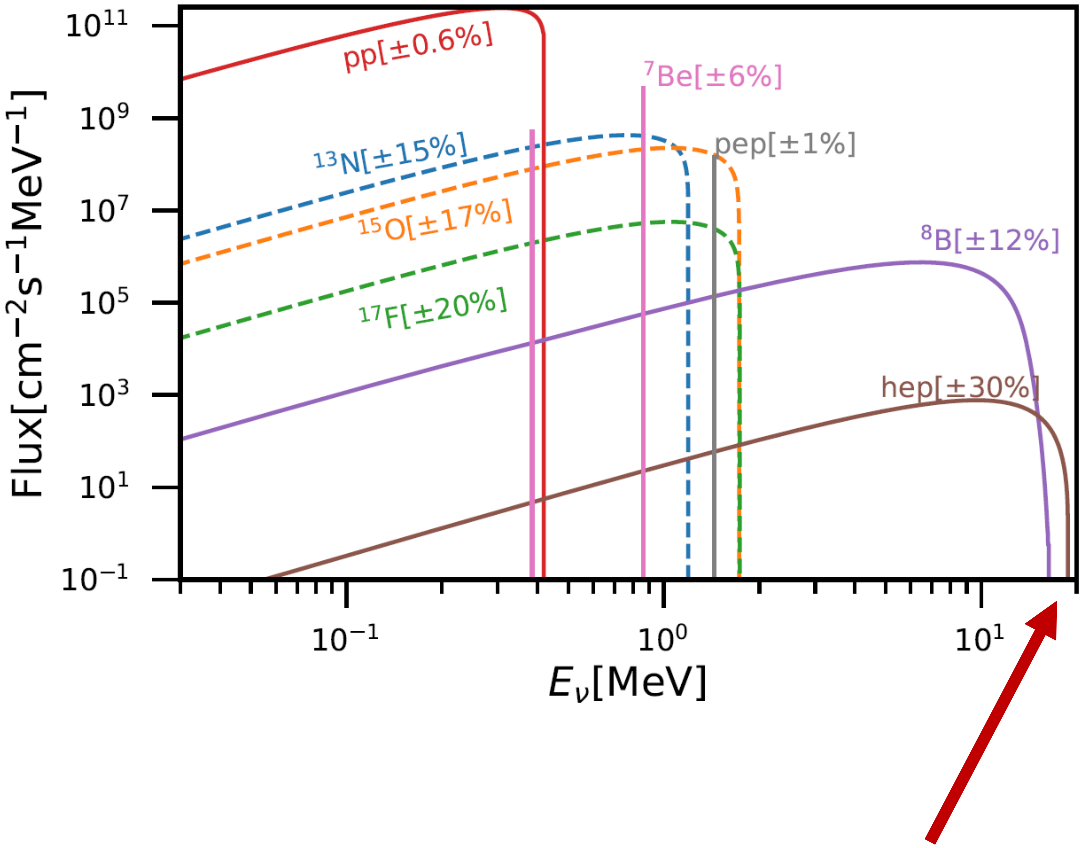
- least experimentally established component
- probe of the ^{3}He distribution
- test of nuclear theory

Key information comes from ^{8}B endpoint

- requires large statistics, good energy reconstruction and resolution to distinguish *hep* neutrinos from the smeared ^{8}B endpoint tail

Search for *hep* neutrinos with SK IV solar data

- 2970 live days



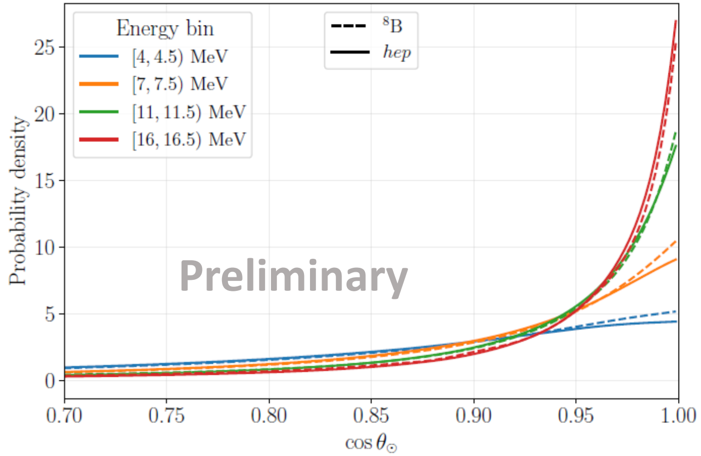
hep neutrinos: higher endpoint energy

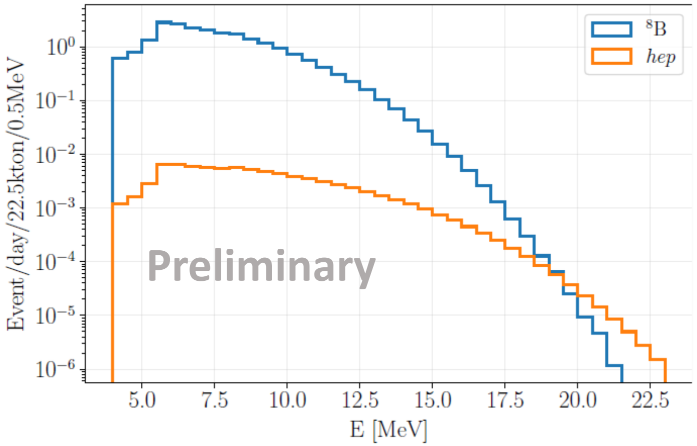
SK IV *hep* Neutrino Search

Poster by Yiyang Wu, #90

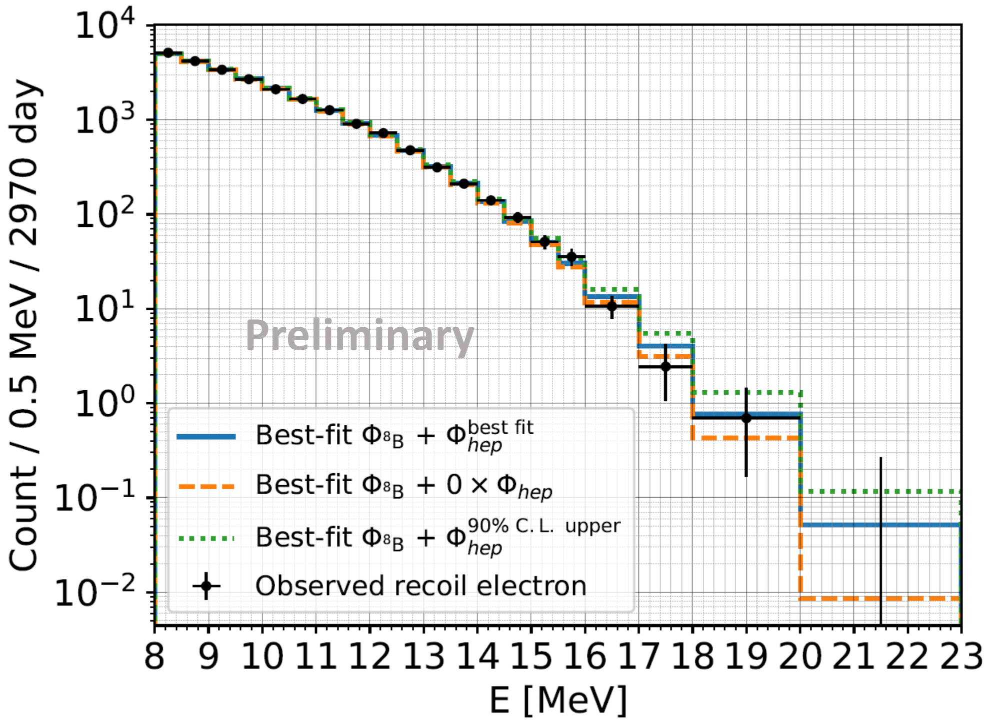
Two-dimensional fit in recoil-electron energy and solar angle

- distinct MC templates for ^{8}B and *hep* components
- non-solar background modeling same as SK standard solar neutrino analysis
- external priors on oscillation parameters from JUNO





^{8}B and *hep* templates in sun angle and recoil-electron energy

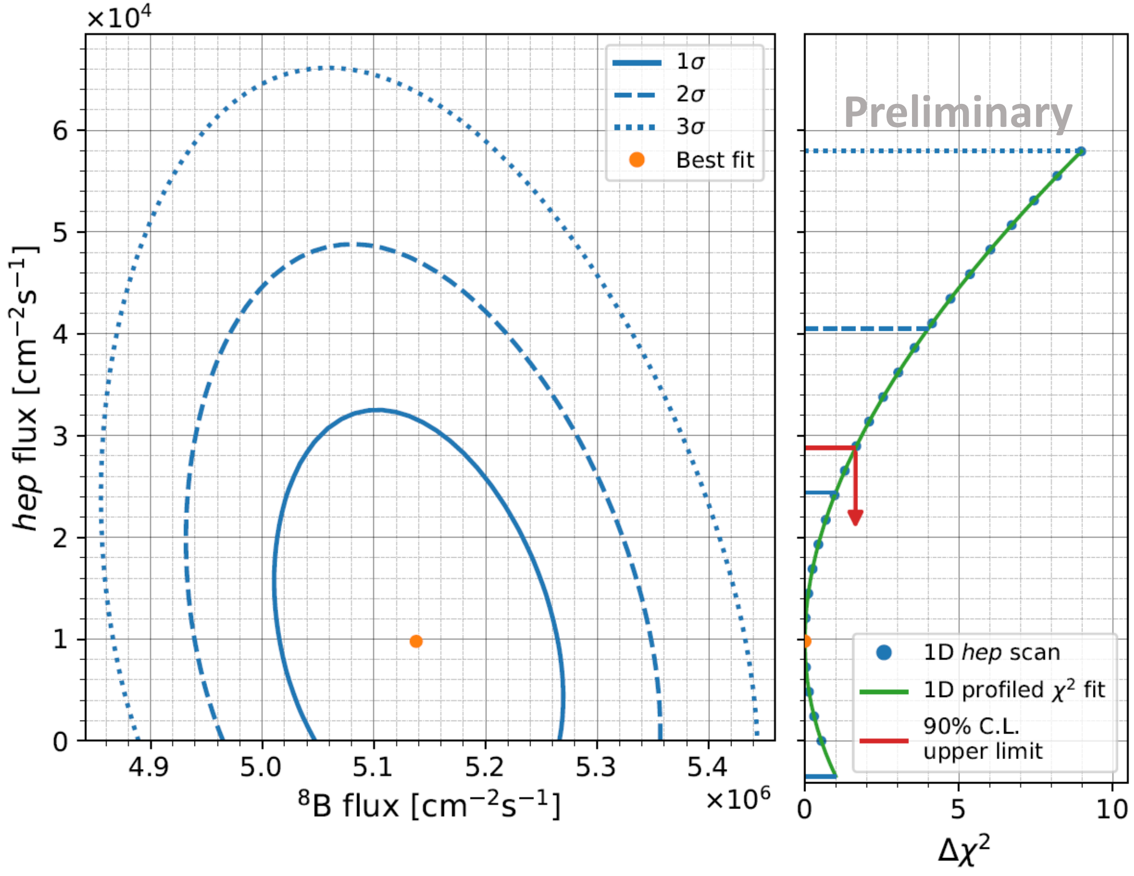


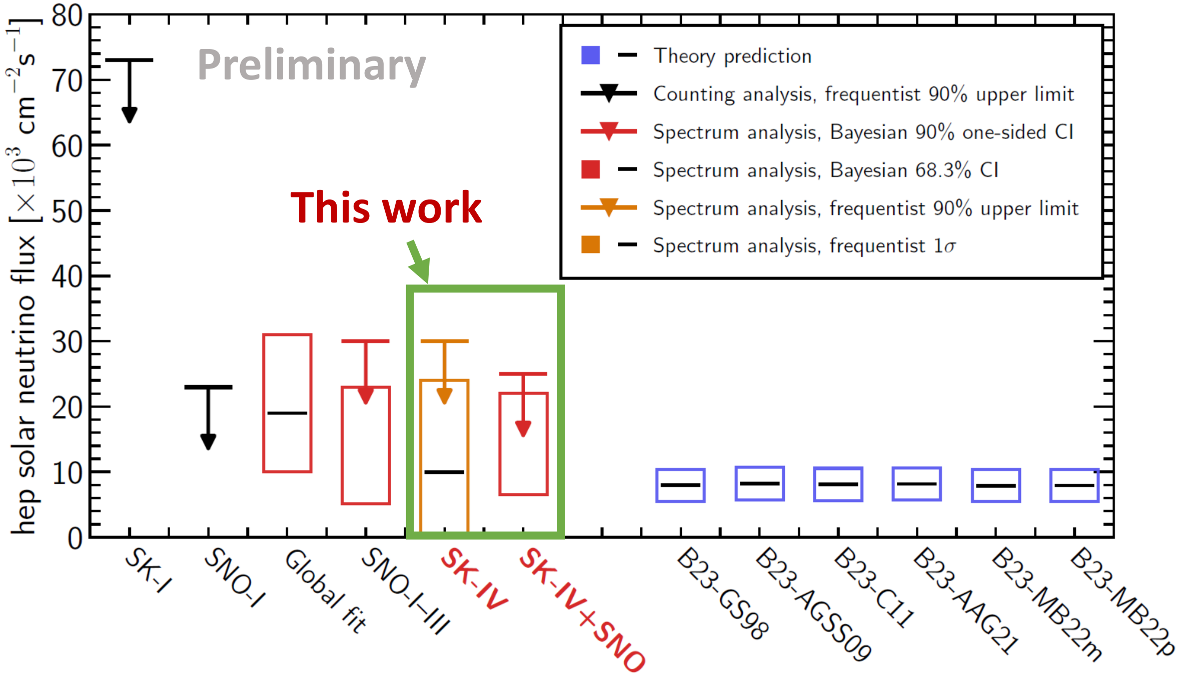
Recoil-e energy spectrum:
Best fit ^{8}B ν flux with

- zero *hep* ν flux
- best fit *hep* ν flux
- 90% C.L. upper limit *hep* ν flux

SK IV *hep* Neutrino Search Result

Poster by Yiyang Wu, #90





Compatible with SNO's upper limits and solar model predictions

Best fit: $\Phi_{hep} = 10^{+14}_{-13} \times 10^3\ \mathrm{cm^{-2}s^{-1}}$

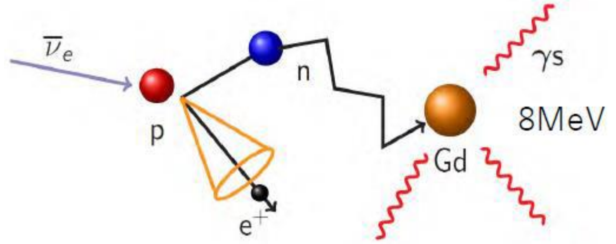
One-sided 90% C.L. upper limit: $\Phi_{hep} < 29 \times 10^3\ \mathrm{cm^{-2}s^{-1}}$

An indication of *hep* neutrino at 1.2σ using Feldman-Cousins method.

Prospect: statistics dominant, plan to combine with other SK data-taking phases

Reactor Neutrinos

Reactor Antineutrinos with SK-Gd

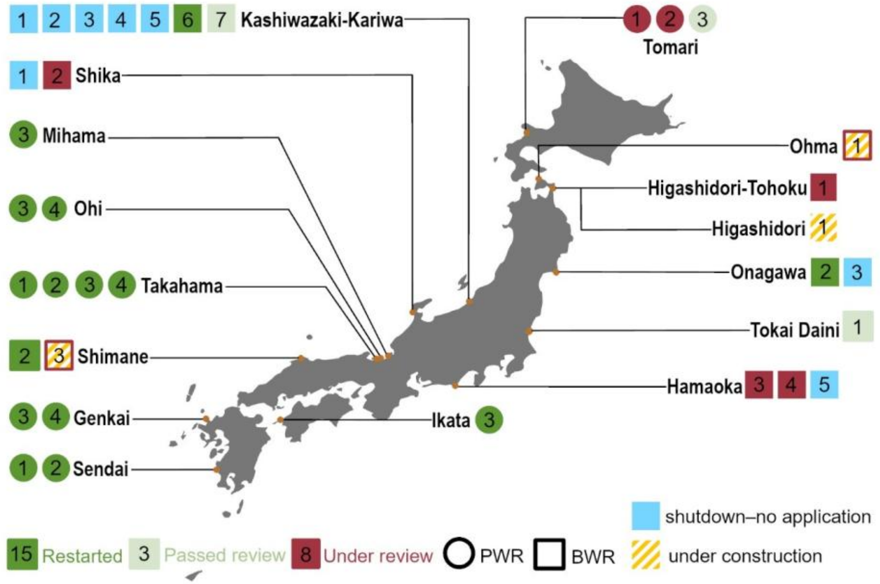


Detection of reactor $\overline{\nu}_e$ in SK is now feasible

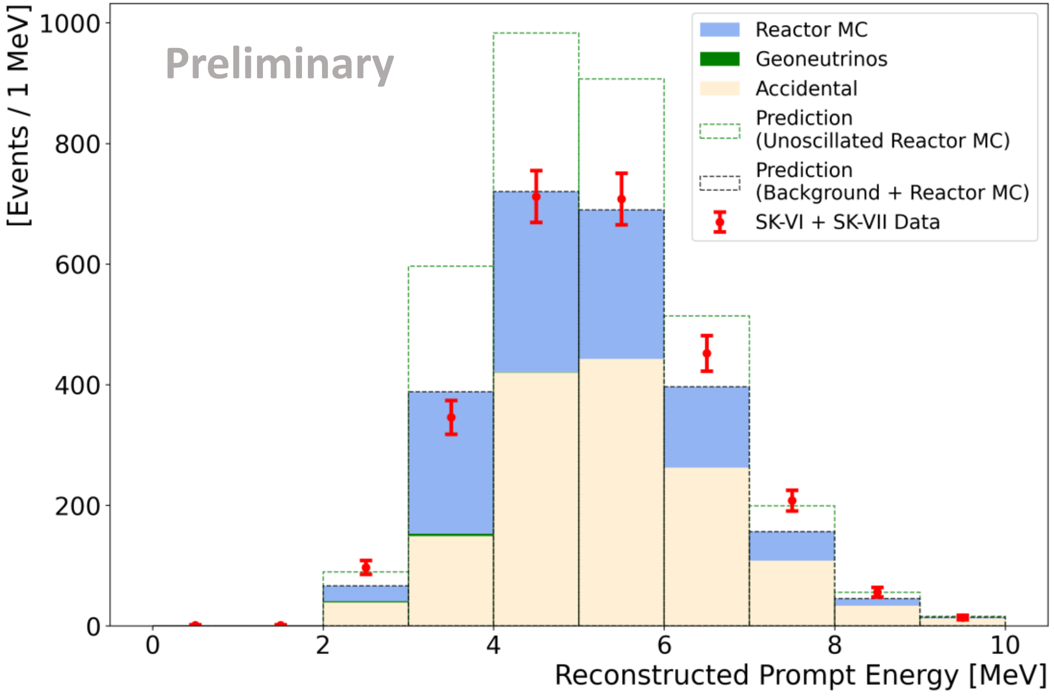
- Gd-reinforced neutron tagging for efficient IBD identification
- Wideband Intelligent Trigger (WIT) with lower threshold

Primarily from the activity of Japanese nuclear power reactors

- $\mathcal{O}(10)$ signal events/day from nearby reactors when active
- Background sources: accidental coincidences, spallation



Statusof Japan's nuclear reactor fleet by plant and reactor number as of February 2026
©U.S. Energy Information Administration



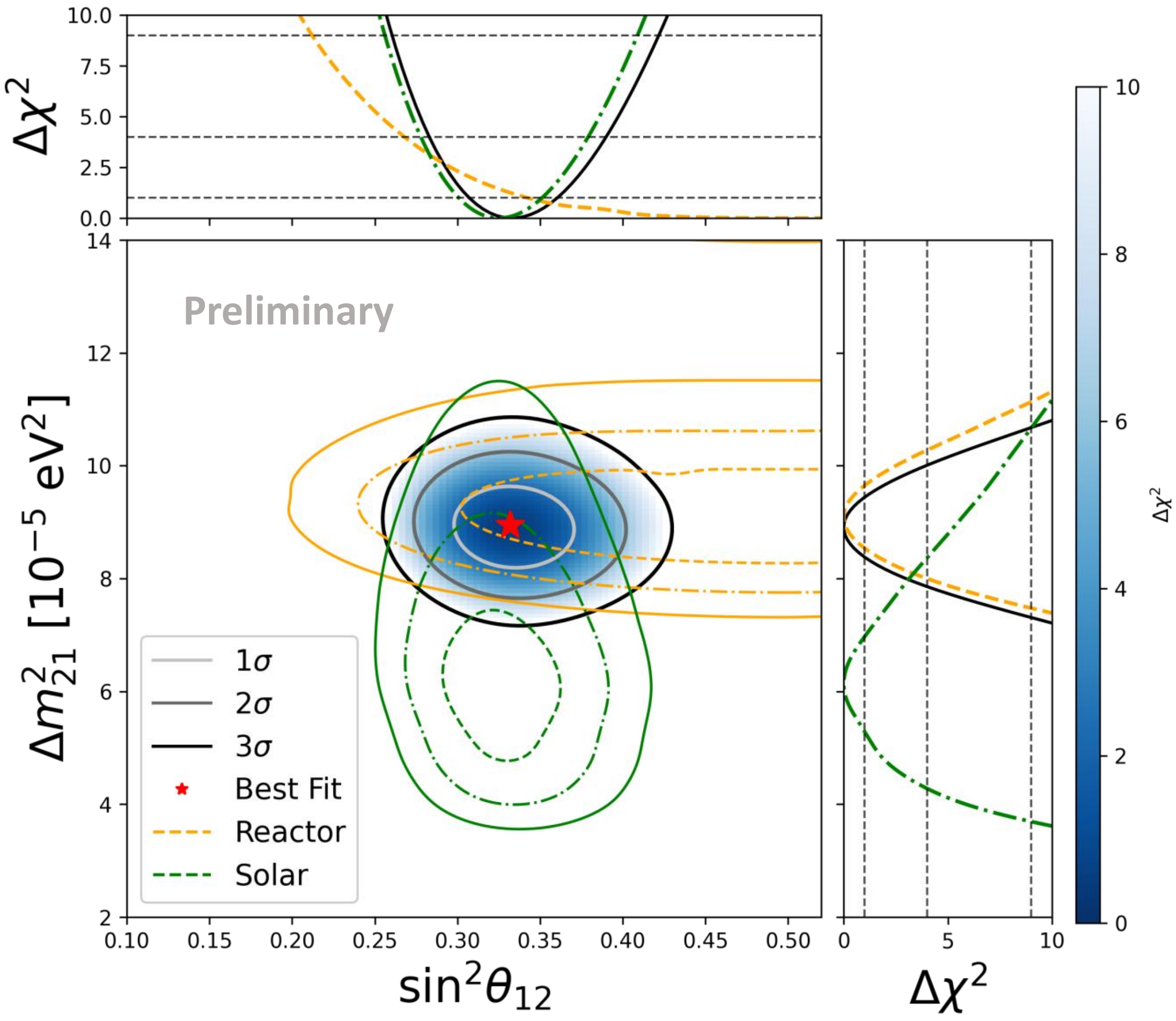
Analyzed SK VI-VII data (~400 live days)

- **reactor $\overline{\nu}_e$ in SK** for the 1st time (6σ)
- solar ν_e & reactor $\bar{\nu}_e$ in one detector

Reactor $\bar{\nu}_e$ + Solar ν_e

	$\sin^2\theta_{12}$	$\Delta m^2_{21}\ [10^{-5}\ \mathrm{eV}^2]$
SK Solar	$0.324^{+0.027}_{-0.023}$	$6.10^{+1.26}_{-0.86}$
SK Reactor	$0.50^{+0.16}_{-0.16}$	$9.08^{+0.55}_{-0.54}$
SK Reactor + Solar	$0.33^{+0.028}_{-0.026}$	$8.94^{+0.46}_{-0.47}$

1.94σ tension between SK I-IV solar neutrino data and SK VI-VII reactor neutrino data



Publication in preparation!

Summary

Summary

New results from Super-Kamiokande:

- Atmospheric ν zenith angle analysis: 1st implementation of ν_τ constraint, favors NO, $\sin^2\theta_{23}$ lower octant, and $\delta_{CP} \approx -\frac{3\pi}{4}$
- Atmospheric ν L/E analysis: new BDT classifier for PC stopping/through-going events, stronger constraint on Δm^2_{32}
- Unitarity violation search w/ atmospheric ν: all consistent with unitary, excellent limits on τ-row
- Solar core and temperature: maximum radius 0.268 $R_\odot$ at 90% C.L., 1st measurement of $T_c \approx 15.6 \times 10^6$ K (SSM high metallicity)
- Solar hep ν search: $\Phi_{hep} = 10^{+14}_{-13} \times 10^3\ \mathrm{cm^{-2}s^{-1}}$ consistent with SSM model predictions and SNO's limits.
- Reactor neutrino measurements: 1st time observed in SK, oscillation fit result 1.94σ away from SK solar ν_e fit

Super-Kamiokande: Multi-purpose neutrino observatory

- Solar neutrinos ($\theta_{12}, \Delta m^2_{21}$)
- Reactor neutrinos ($\theta_{12}, \Delta m^2_{21}$)
- Atmospheric neutrinos ($\theta_{23}, \Delta m^2_{32}, \delta_{CP}, \mathrm{MO}$)
- Accelerator neutrinos (T2K: $\theta_{23}, \Delta m^2_{32}, \delta_{CP}, \theta_{13}$)
- Supernova neutrinos (Talk by H. Sekiya tomorrow)

Summary

New results from Super-Kamiokande:

- Atmospheric ν zenith angle analysis: 1st implementation of ν_τ constraint, favors NO, $\sin^2\theta_{23}$ lower octant, and $\delta_{CP} \approx -\frac{3\pi}{4}$
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More on supernova neutrinos
Hiroyuki Sekiya
June 25th Thursday 11:30 am

… and fruitful results in our posters.

Presenter	Title	Poster #
Yota Hino	Modification on thermal motion in Geant4 for neutron capture simulation in Gadolinium loaded water	38
Guillaume Pronost	Super-Kamiokande's Supernova monitoring: A trigger for multi-messenger research	84
Yiyang Wu	Search for Solar hep Neutrinos with the Full Super-Kamiokande-IV Dataset	90
Mao Nishigami	Neutron Tagging Efficiency Evaluation in the Super-Kamiokande Gd Phases	102
Tomoaki Tada	Measurement of the kaon-to-pion ratio for the atmospheric neutrino using the cosmic-ray muon data in Super-Kamiokande	217
Ben Jargowsky	Constraining Tau Neutrino Appearance to Improve the Measurement of the Mass Ordering with Atmospheric Neutrinos in Super-Kamiokande	225
Fumi Nakanishi	Search for Neutrinos Associated with a Failed Supernova Candidate in M31 with Super-Kamiokande	228
Mariusz Girgus	Oscillatory pattern of atmospheric muon neutrino disappearance in Super-Kamiokande	230
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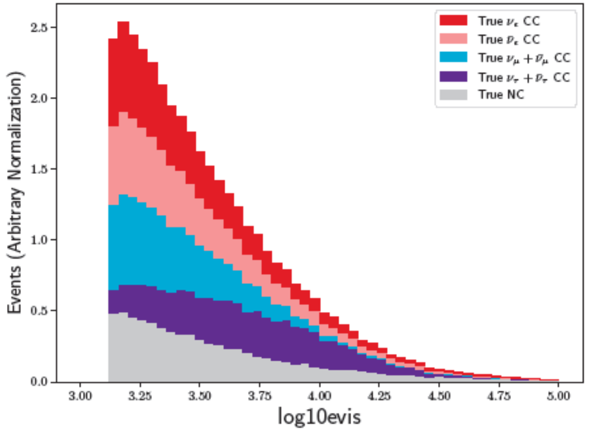
Saki Fujita	New Results from the Diffuse Supernova Neutrino Background Search at Super-Kamiokande	360
Keita Saito	Study of coincident muon bundles at KamLAND and Super-Kamiokande	415
Bin Zhang	SRN Search with an Expanded Time Window at Super-Kamiokande-IV	424
Licheng Feng	Constraining Atmospheric NCQE Backgrounds for Super-Kamiokande DSNB Searches using T2K Data	502
Yifan Jiang	Solar core size limits and temperature probe using 5695 days of Super-Kamiokande data	573

Thank you!

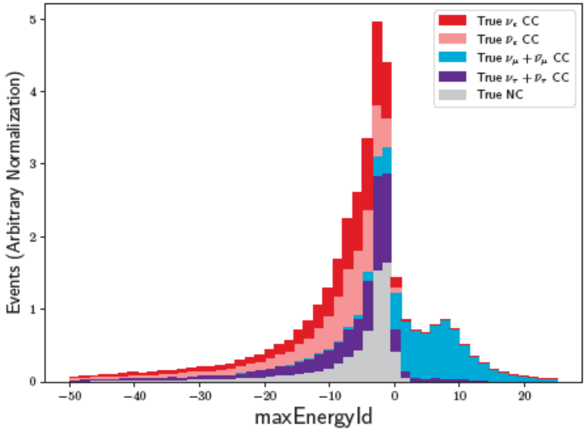
Backup

Statistically Identify ν_τ

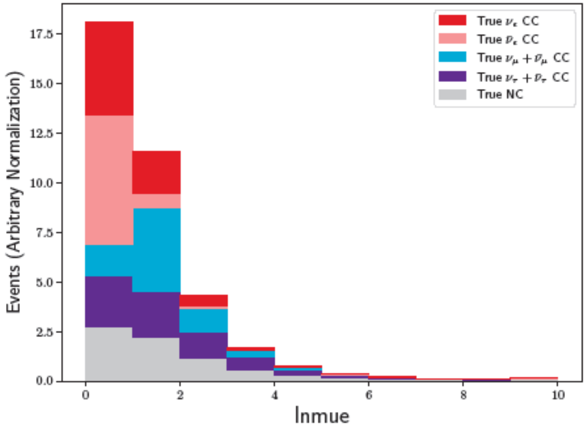
Preliminary



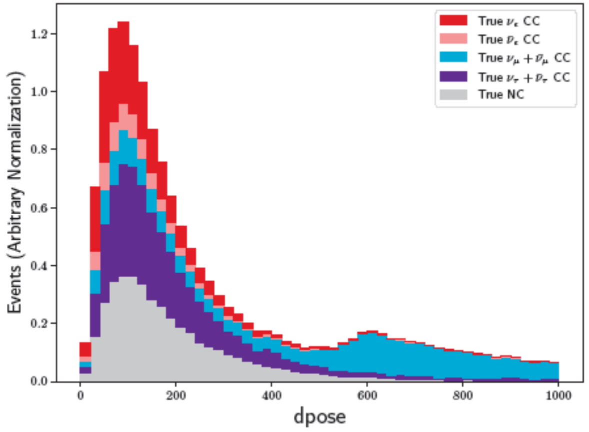
1. higher visible energy



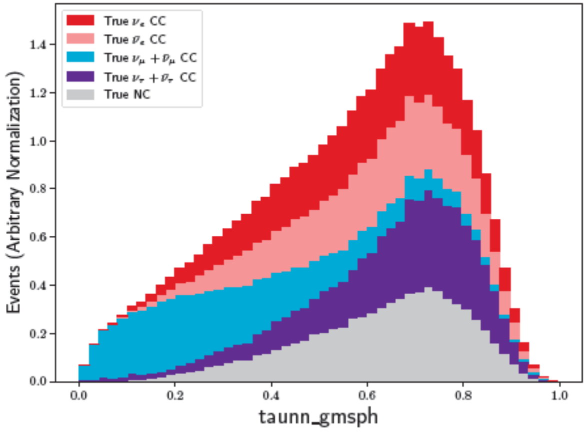
2. showering most energetic ring



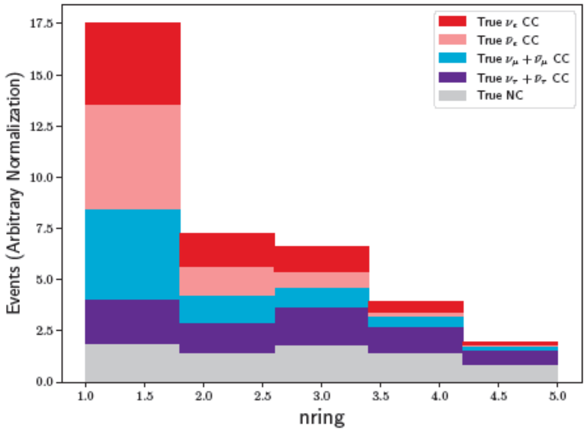
3. more decay electrons



4. smaller distance of furthest decay electron



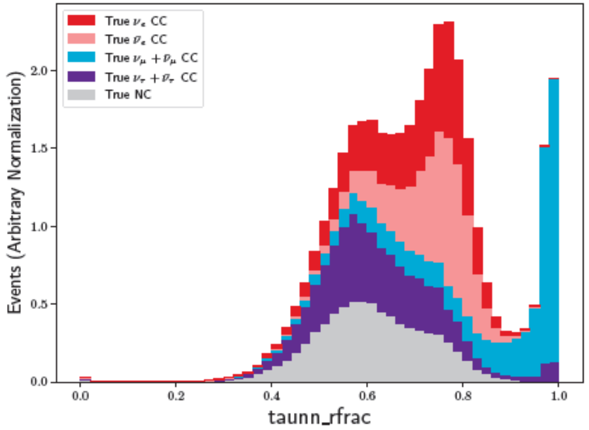
5. more spherical hit cluster



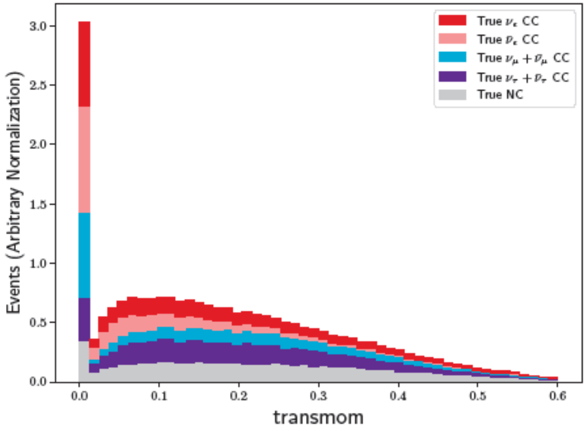
6. more rings

Statistically Identify ν_τ

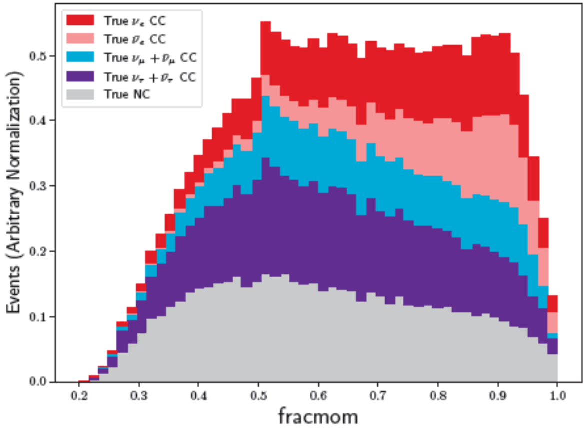
Preliminary



7. PE more evenly distributed among rings



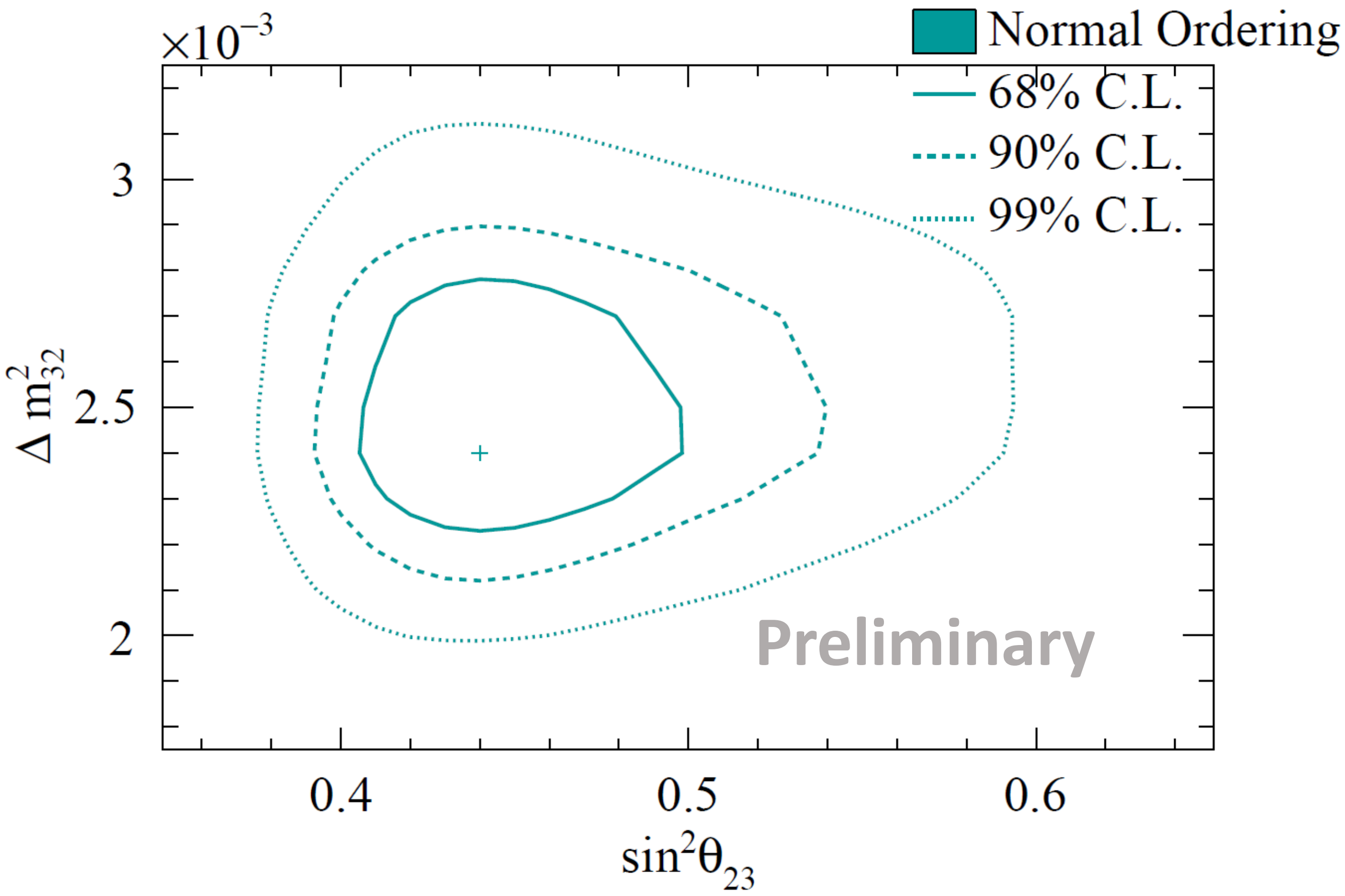
8. higher transverse momentum of the most energetic ring



9. lower momentum fraction carried by the most energetic ring

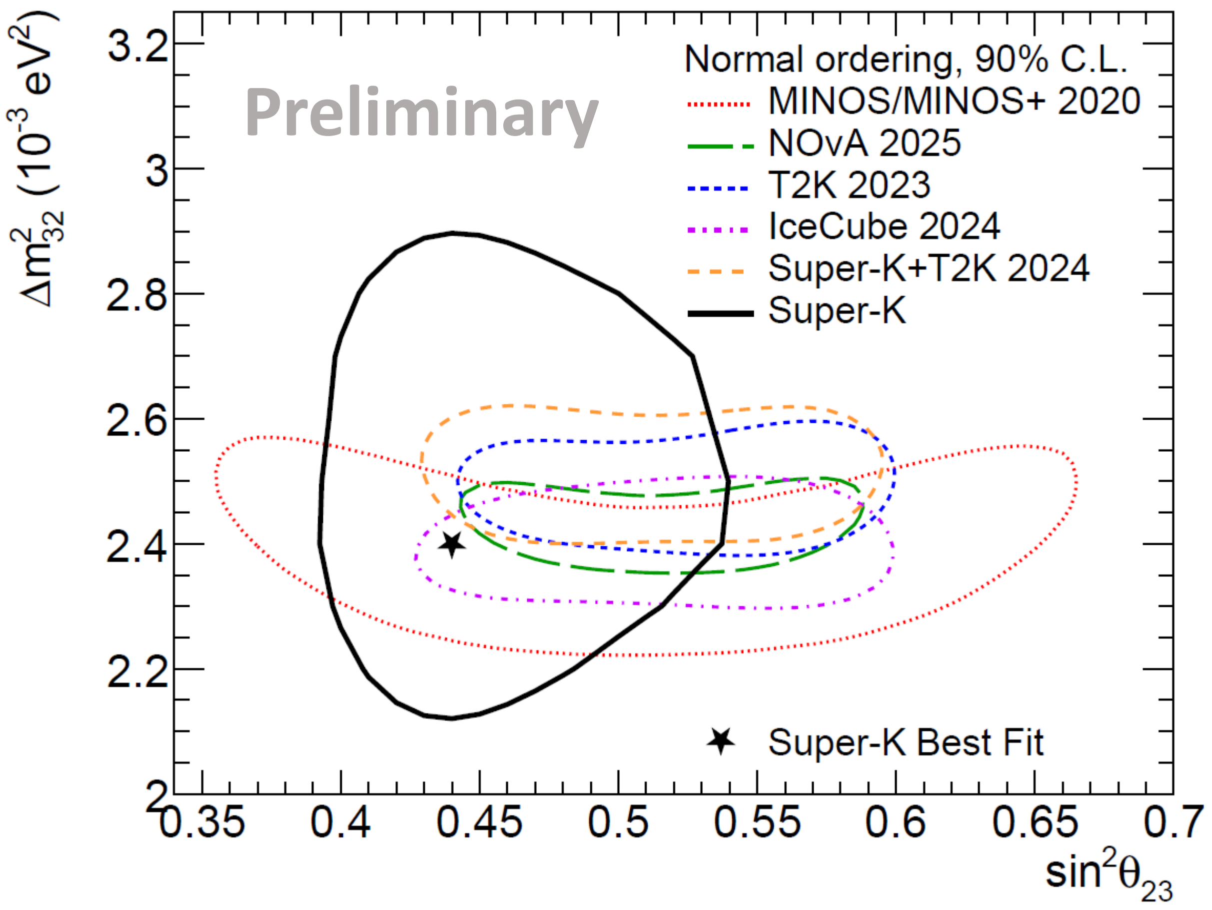
SK I-VI $\sin^2\theta_{23} - \Delta m^2_{32}$

Poster by Ben Jargowsky, #225



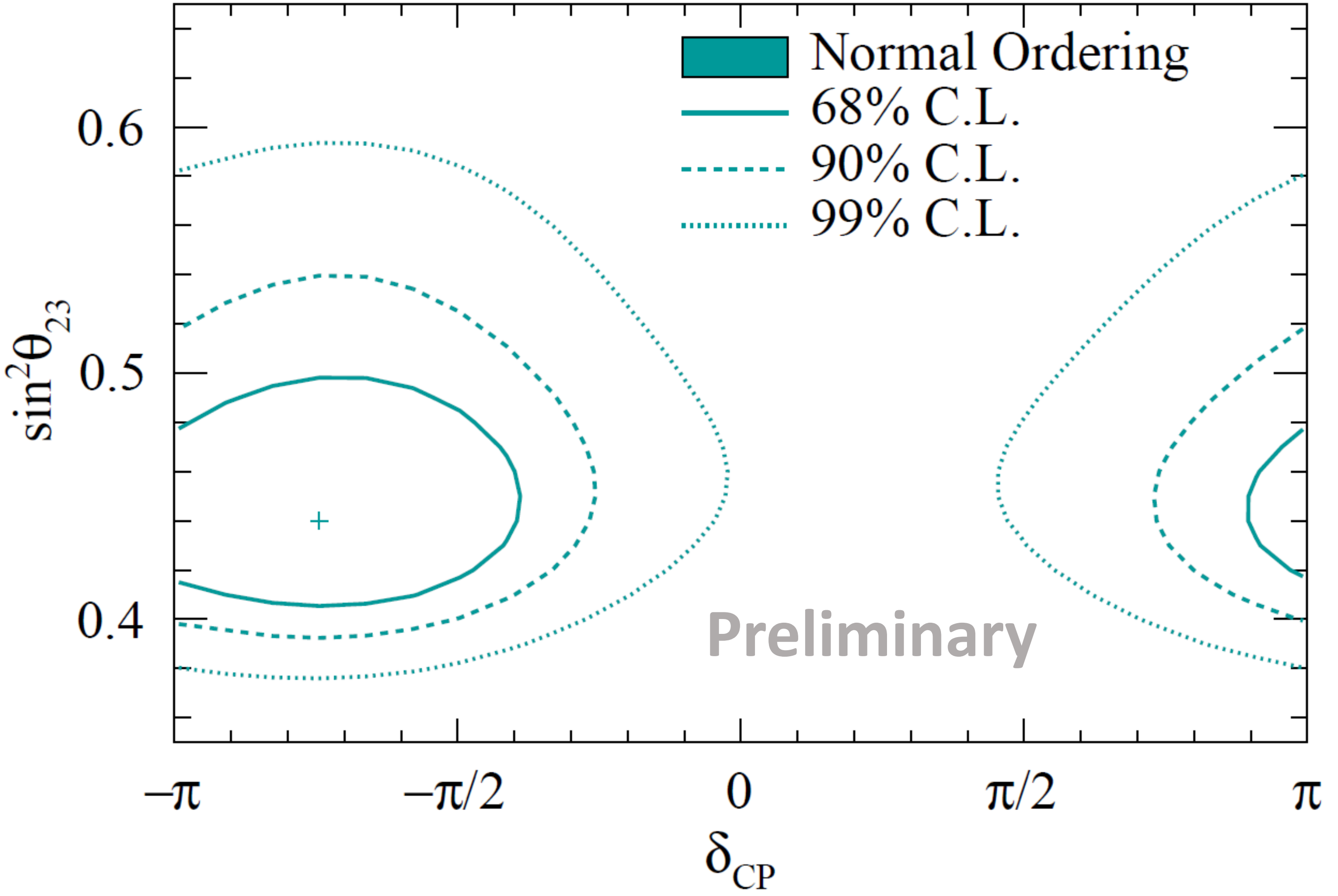
SK I-VI $\sin^2\theta_{23} - \Delta m^2_{32}$

Poster by Ben Jargowsky, #225



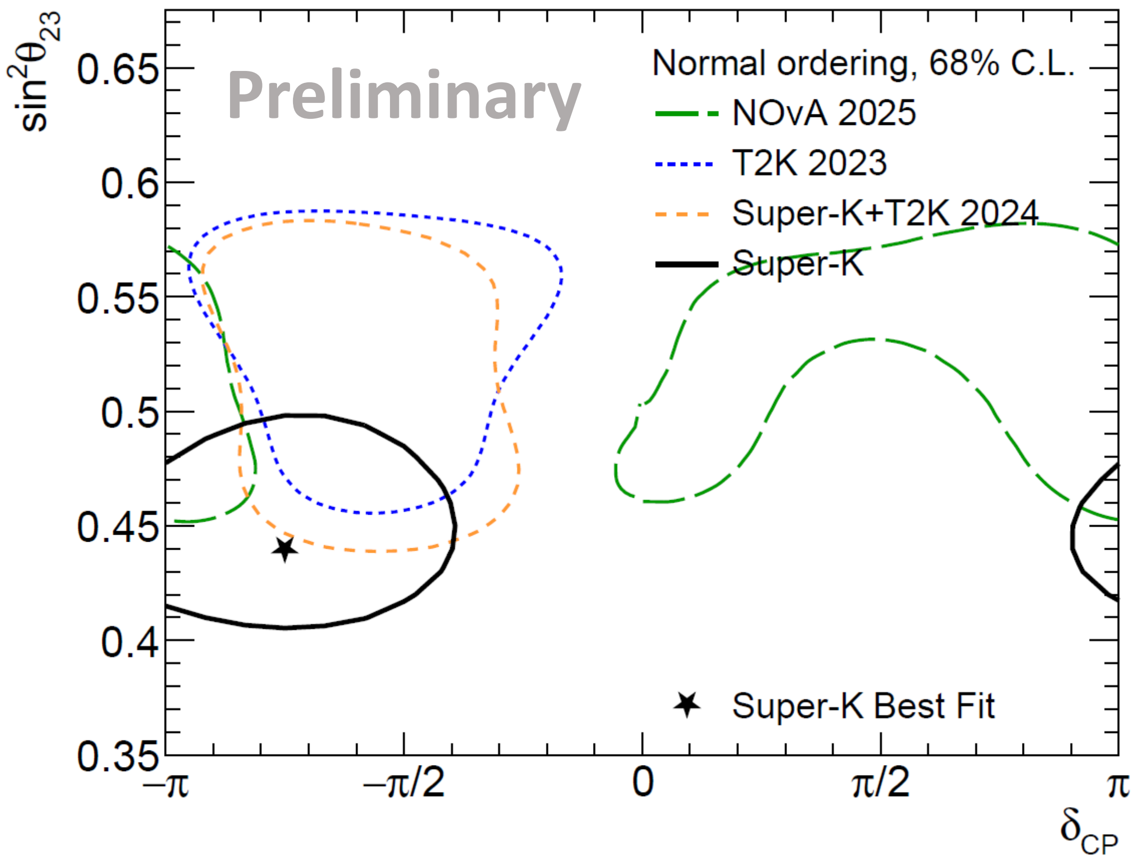
SK I-VI $\sin^2\theta_{23} - \delta_{CP}$

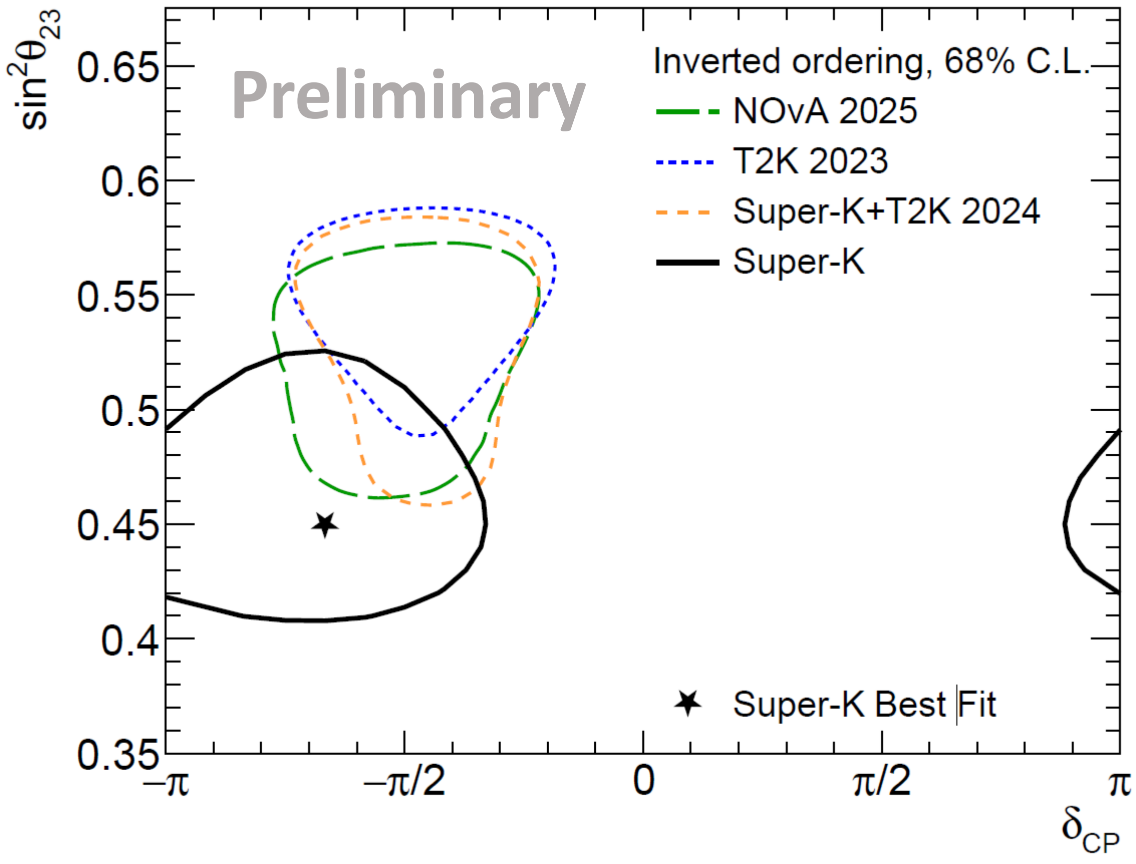
Poster by Ben Jargowsky, #225



SK I-VI $\sin^2\theta_{23} - \delta_{CP}$

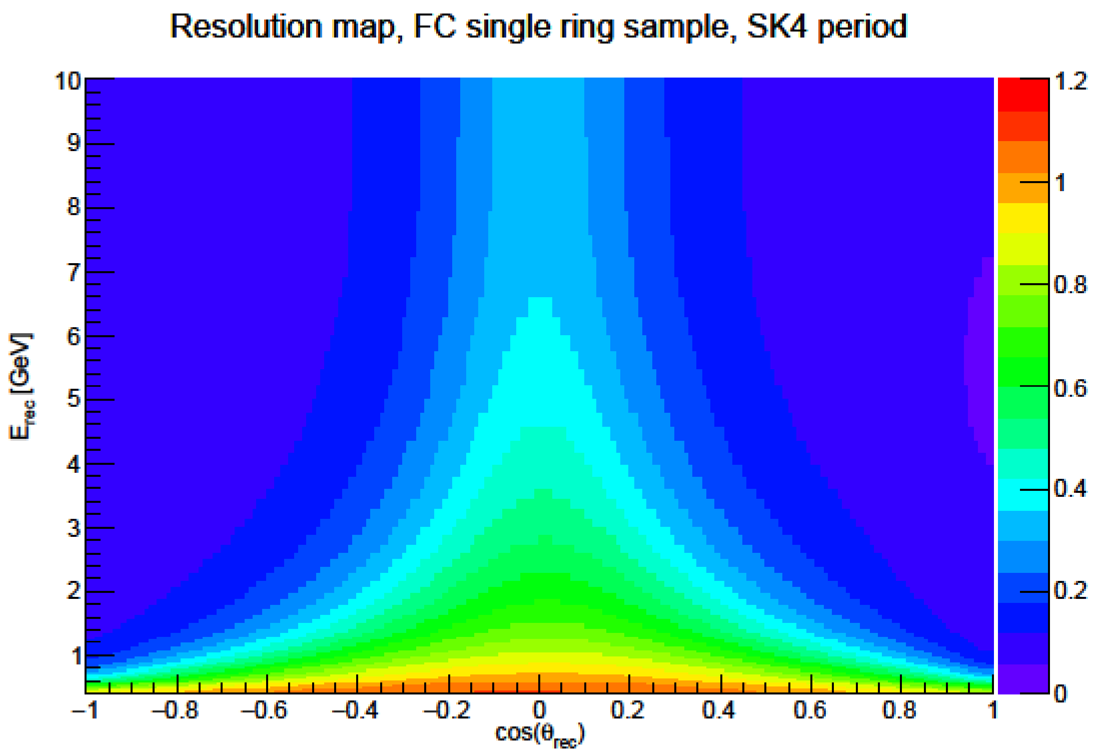
Poster by Ben Jargowsky, #225





Resolution Map

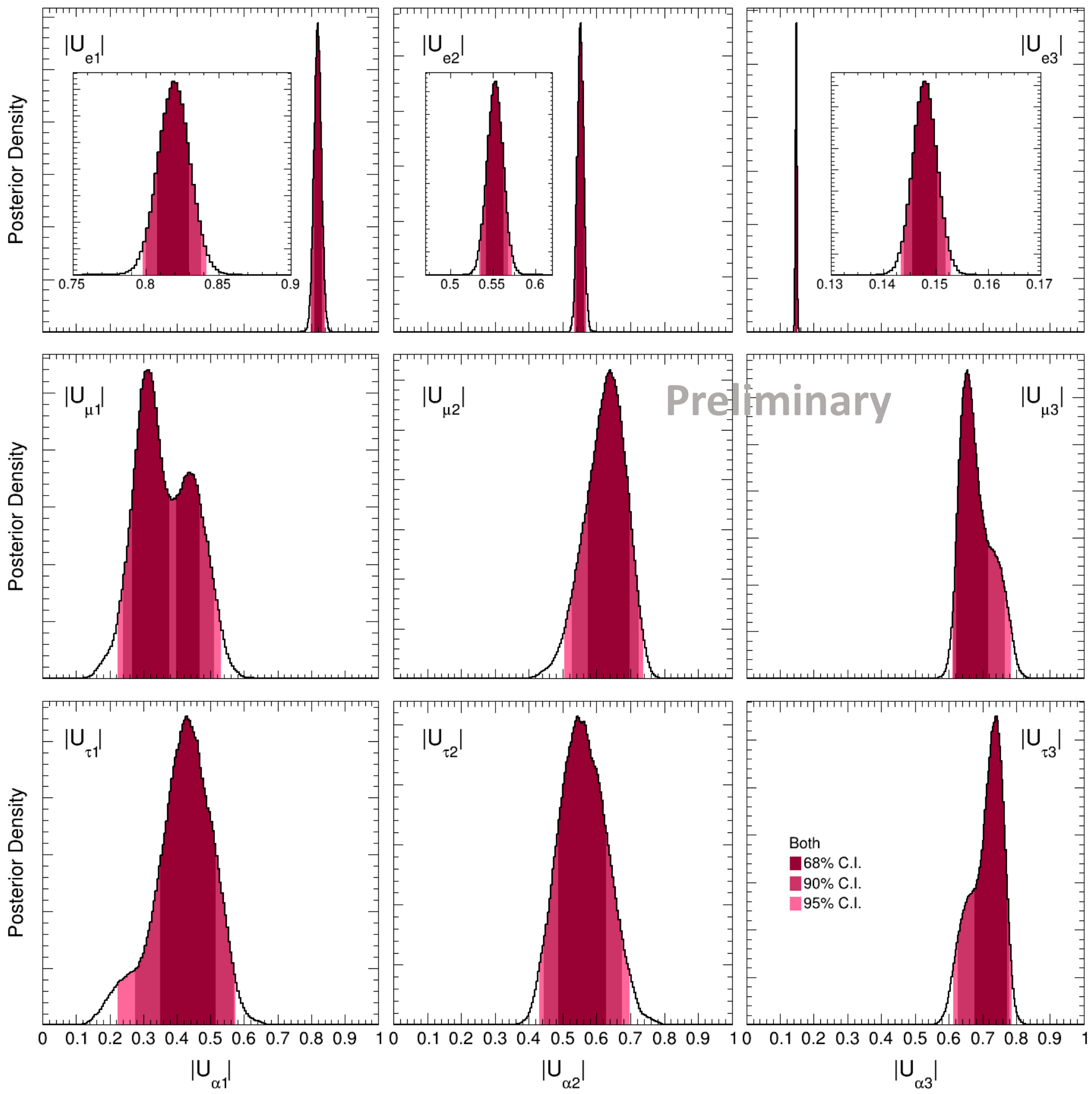
Preliminary



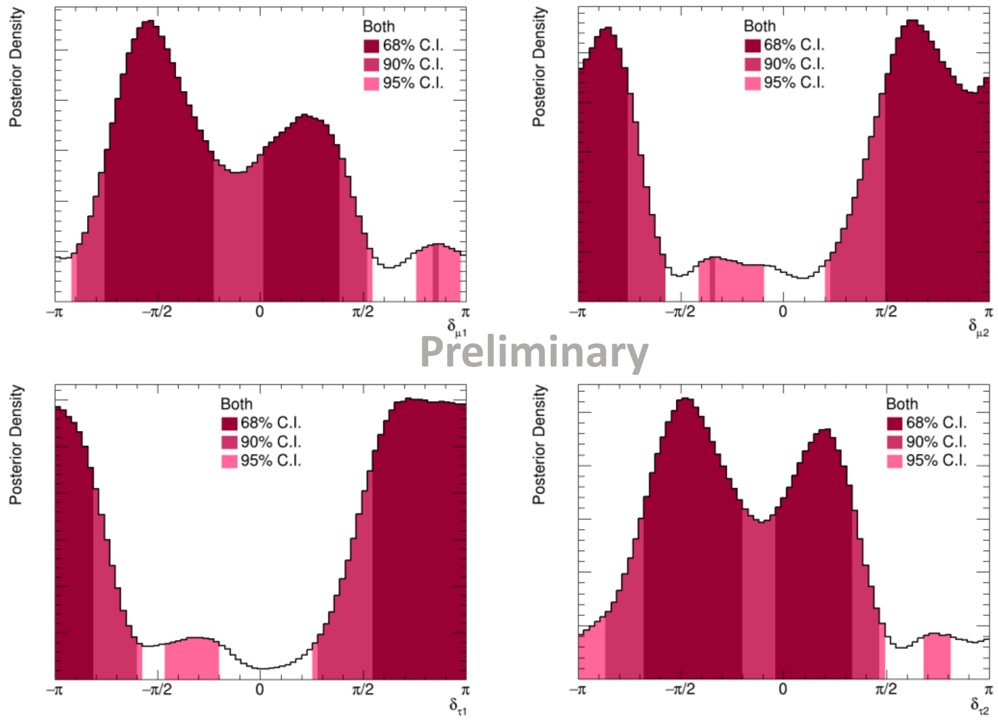
High resolution: high energy upward/downward going events

Low resolution: low energy events / horizontal events

Matrix Element Posteriors



9 magnitudes



4 phases

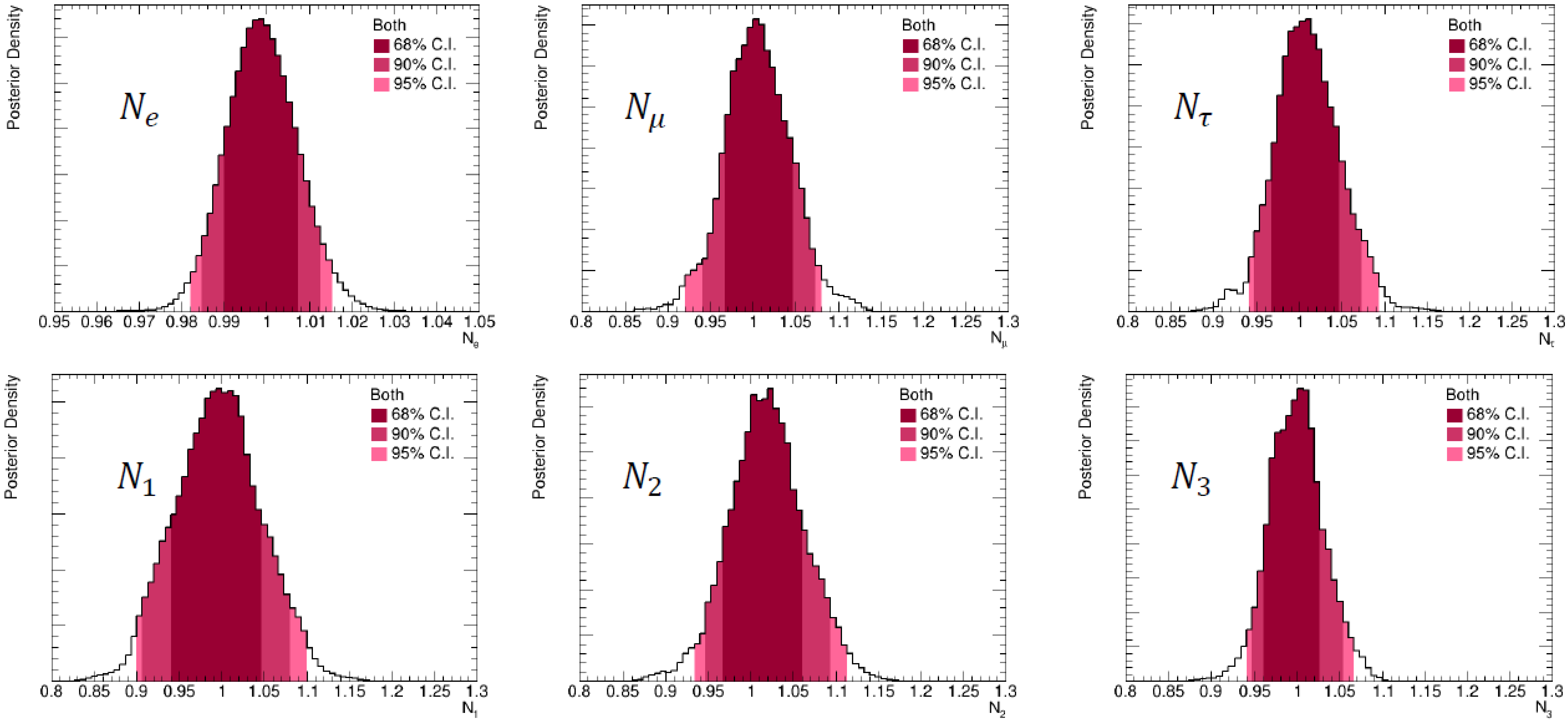
$$\delta_{\alpha i} = \tan^{-1}\left(\frac{\mathrm{Im}(U_{\alpha_i})}{\mathrm{Re}(U_{\alpha i})}\right) - \delta_{CP}$$

Stronger constraint on tau row than other GUV results

Posteriors of matrix elements in GUV are in agreement with unitary results.

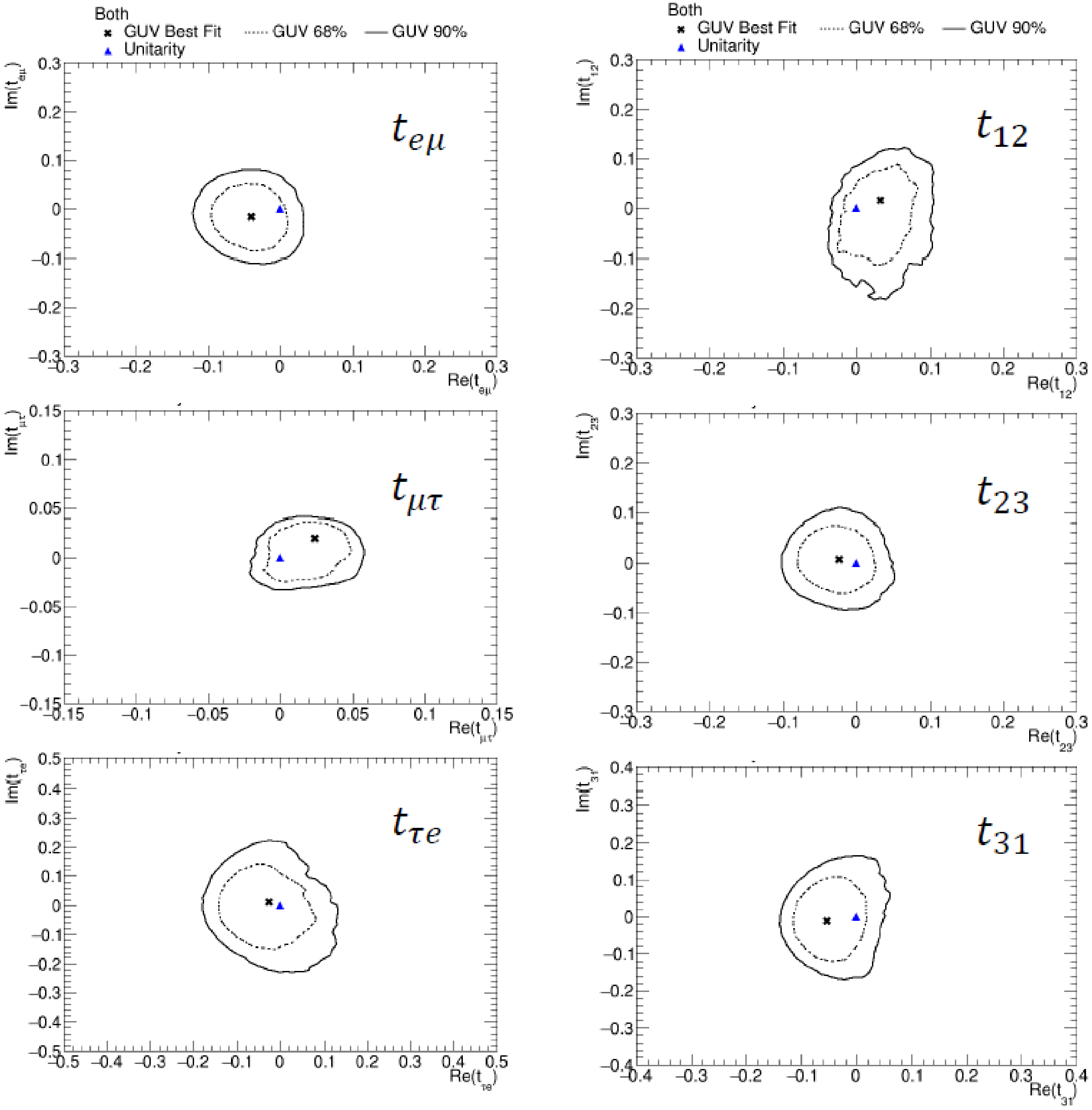
Unitarity Conditions: Normalizations

Preliminary

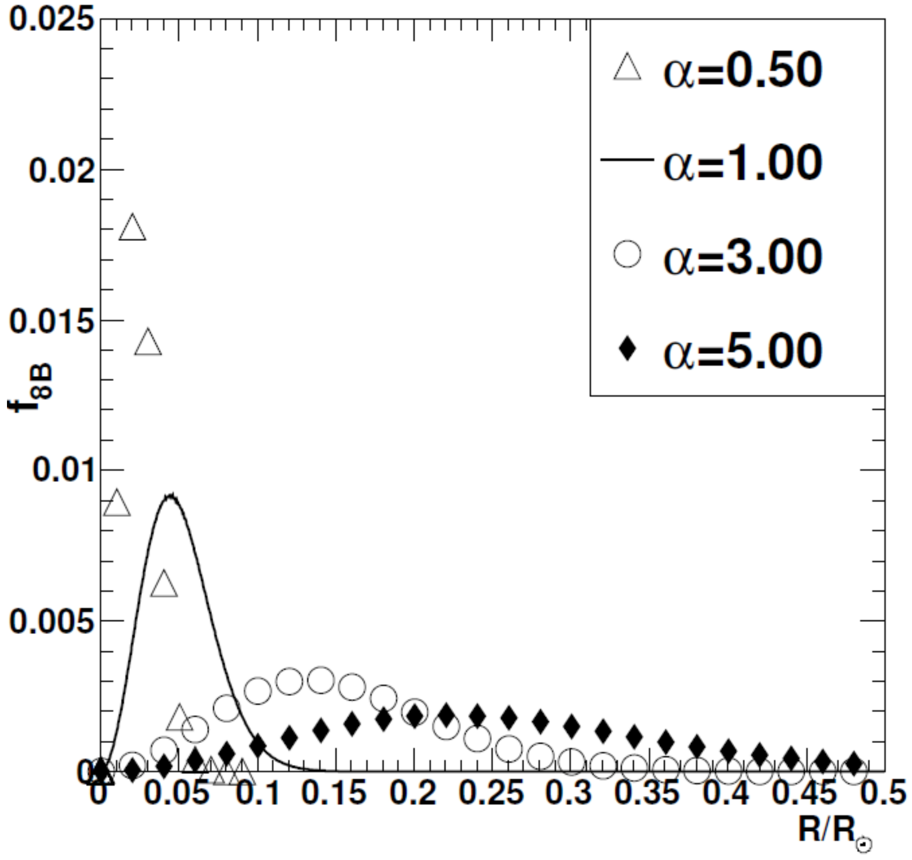


Unitarity Conditions: Closures

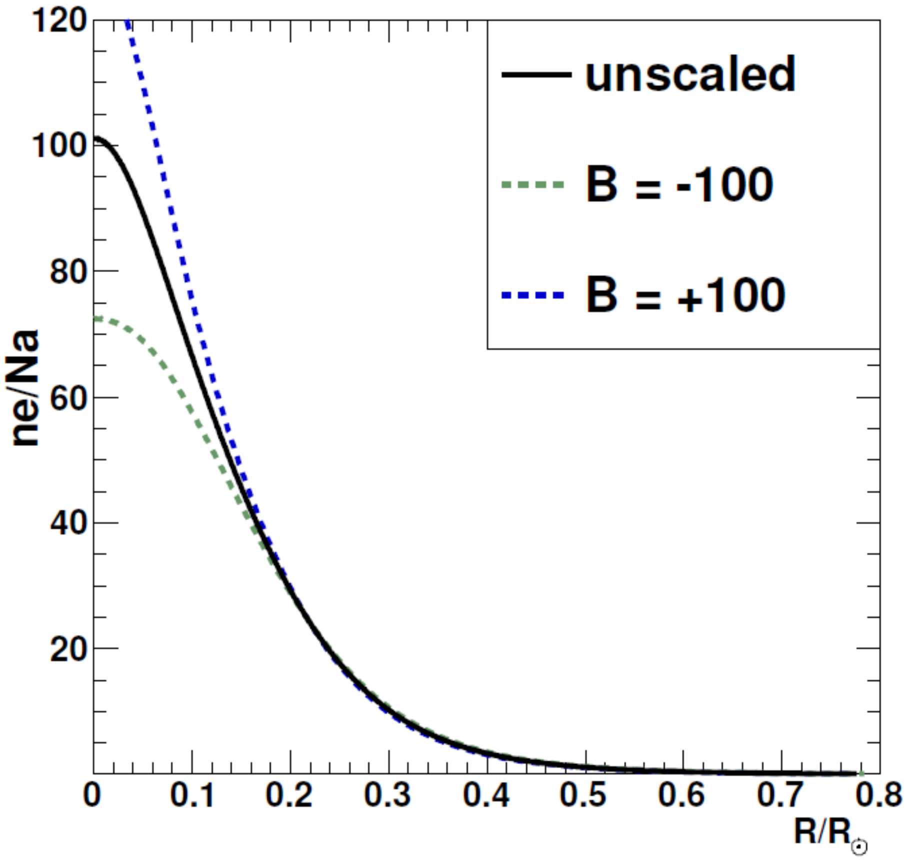
Preliminary



SK VI Solar Core

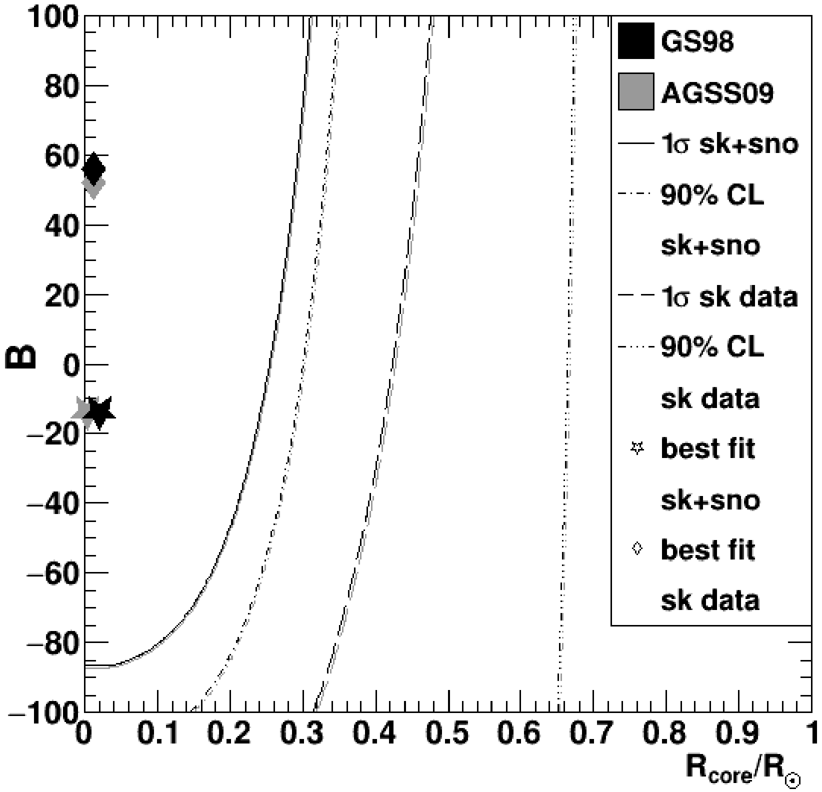


^{8}B neutrino generation profile scaling

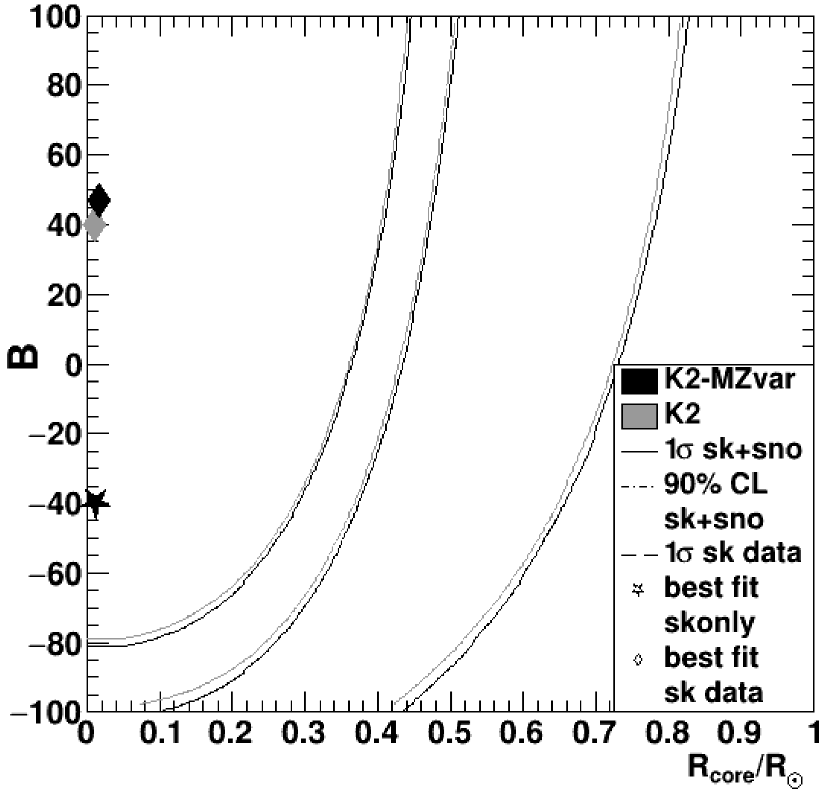


electron density scaling

SK VI Solar Core



B16 best fit contour

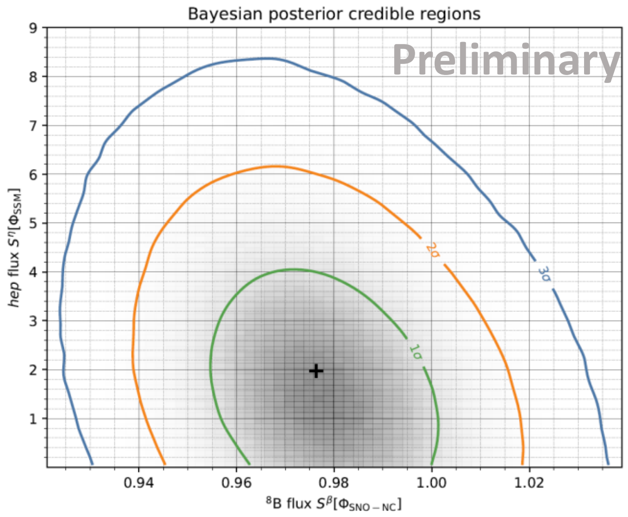


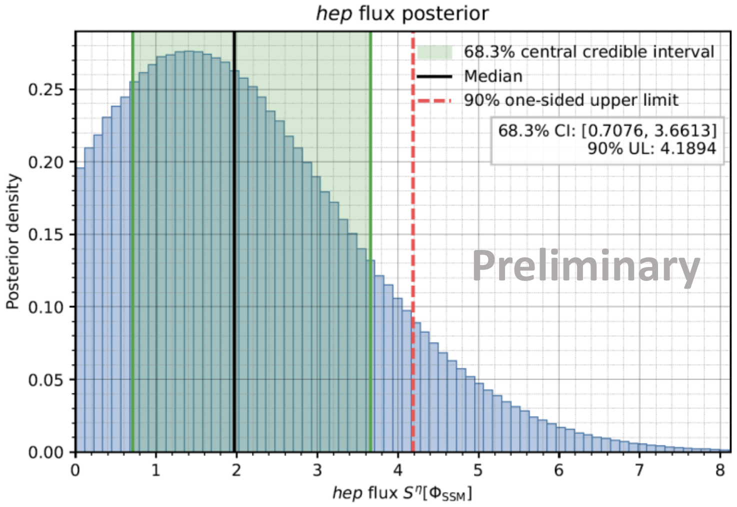
K2 best fit contour

SK IV *hep* Search Bayesian Result

Poster by Yiyang Wu, #90

SK IV

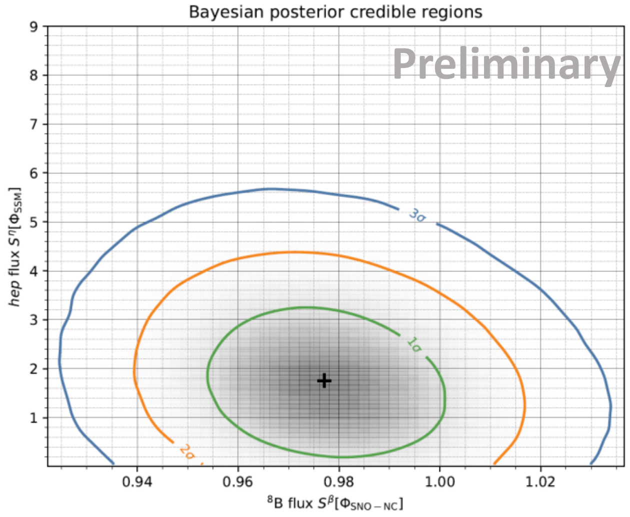


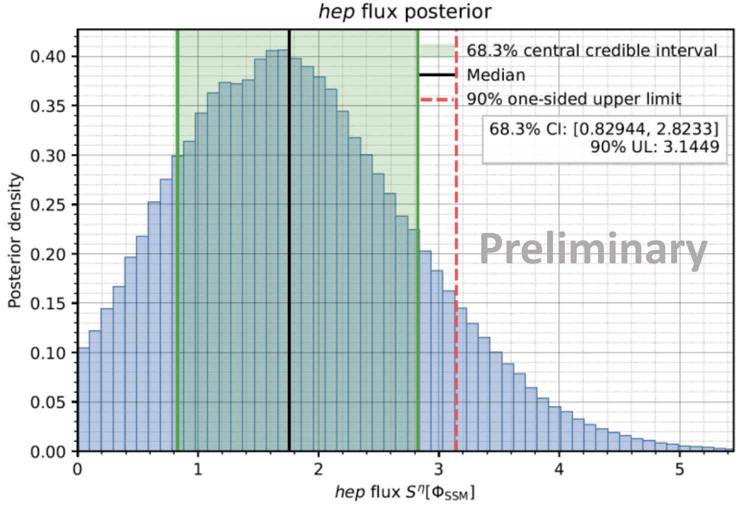


SK IV
90% credible interval:
$\Phi_{hep} < 32 \times 10^3\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$

68.3% credible interval:
$\Phi_{hep} \in [5,28] \times 10^3 \mathrm{cm}^{-2}\mathrm{s}^{-1}$

SK IV+SNO

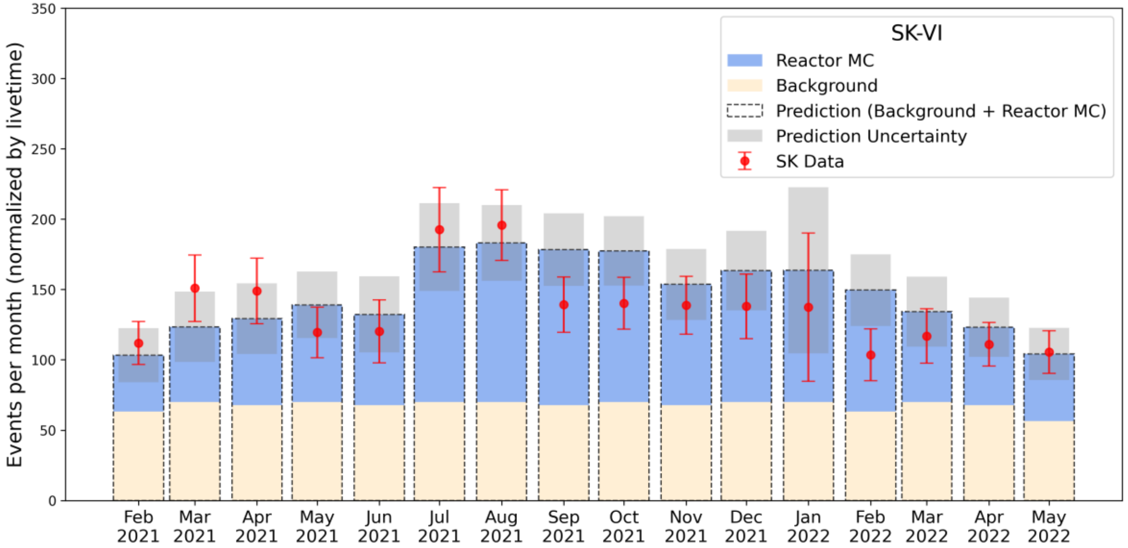


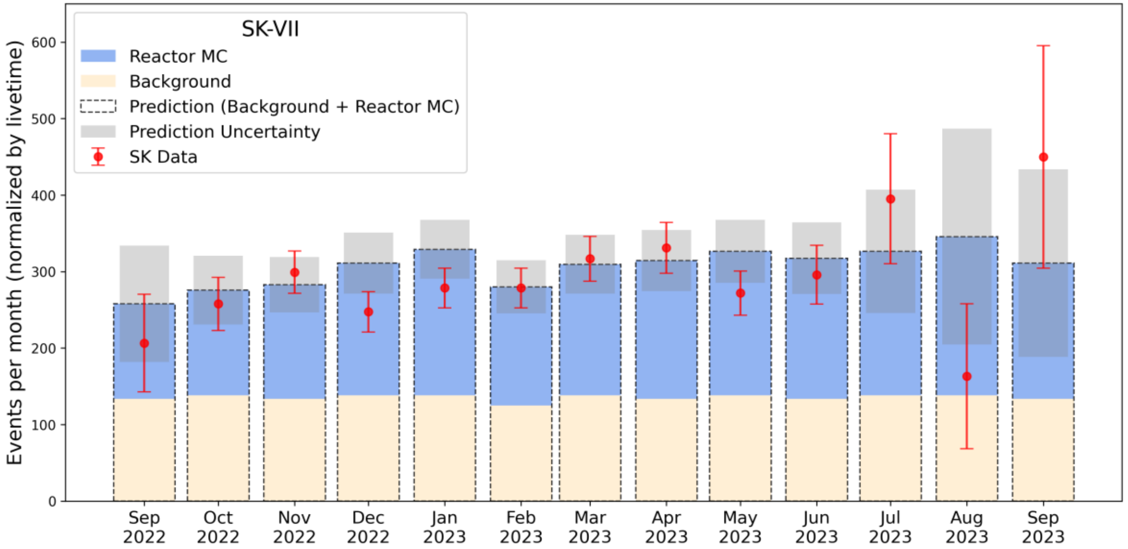


SK IV + SNO
90% credible interval:
$\Phi_{hep} < 24 \times 10^3\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$

68.3% credible interval:
$\Phi_{hep} \in [6,22] \times 10^3 \mathrm{cm}^{-2}\mathrm{s}^{-1}$

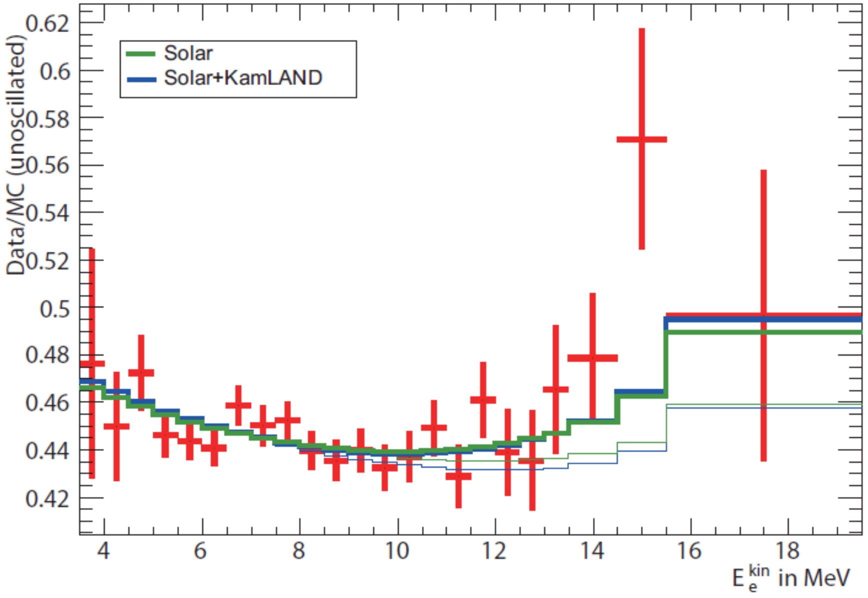
SK VI-VII Reactor Neutrinos

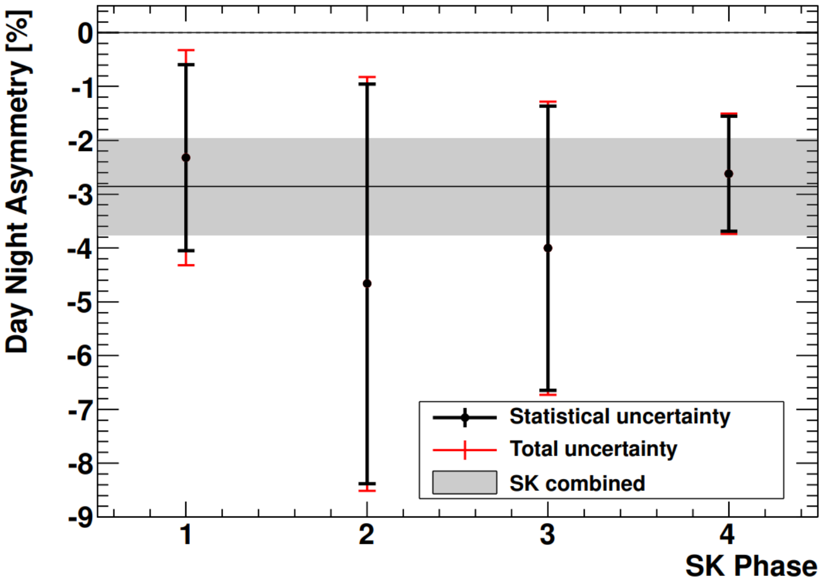


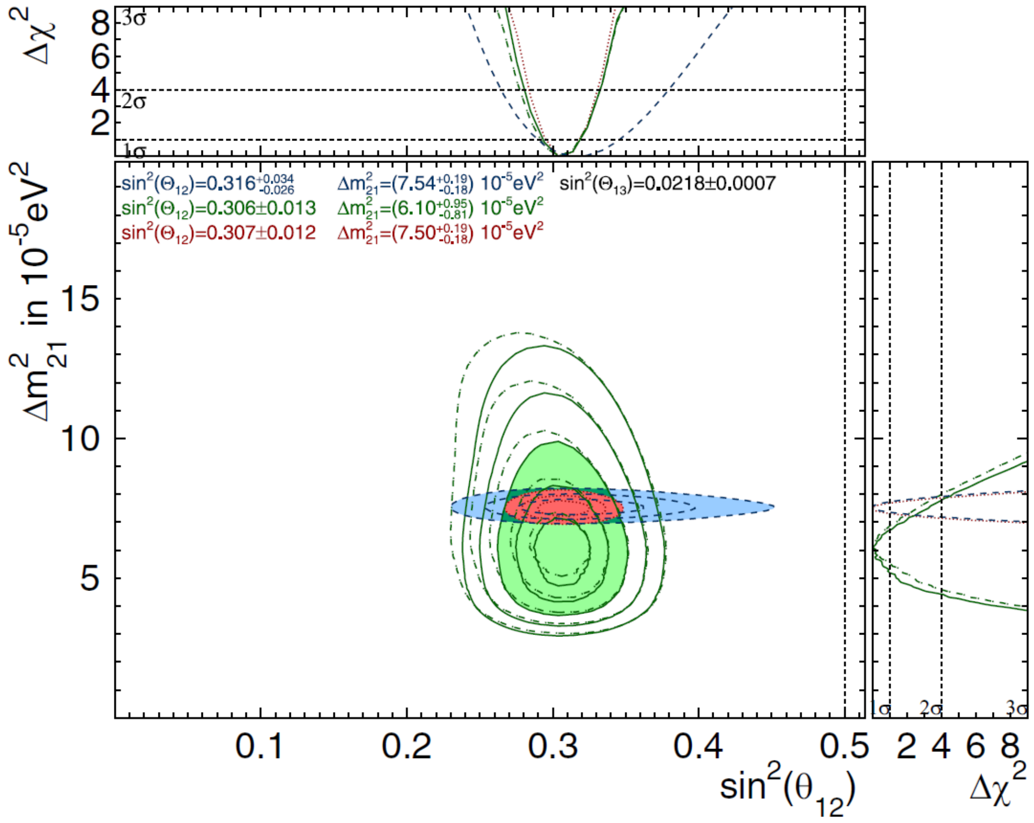


SK I-IV Solar Neutrino Measurements

SK I-IV PRD 109 (9), 092001 (2024)







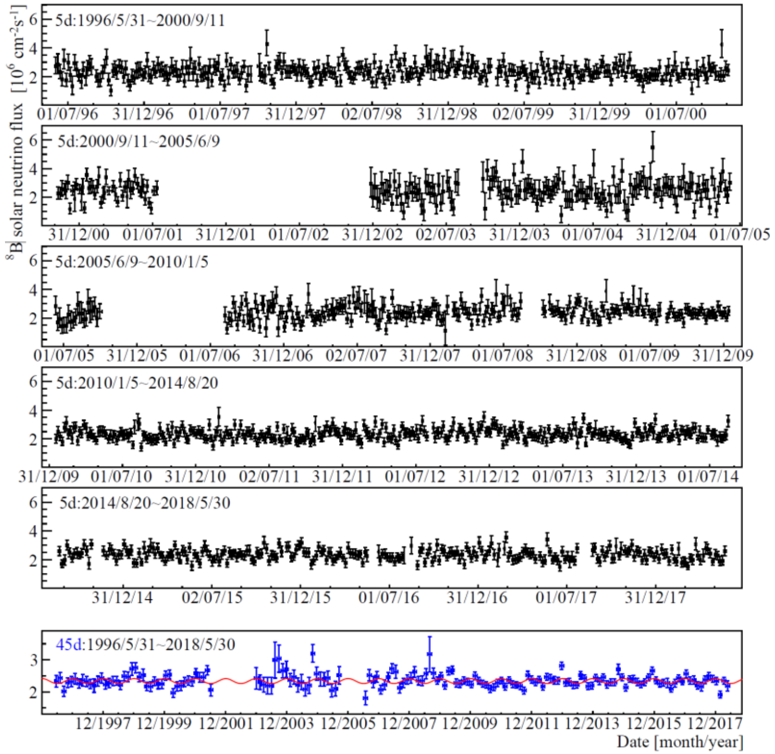
^{8}B neutrino recoil-electron kinetic energy spectrum: slightly favors up-turn

Observed day-night asymmetry: Earth's matter effects in solar neutrinos

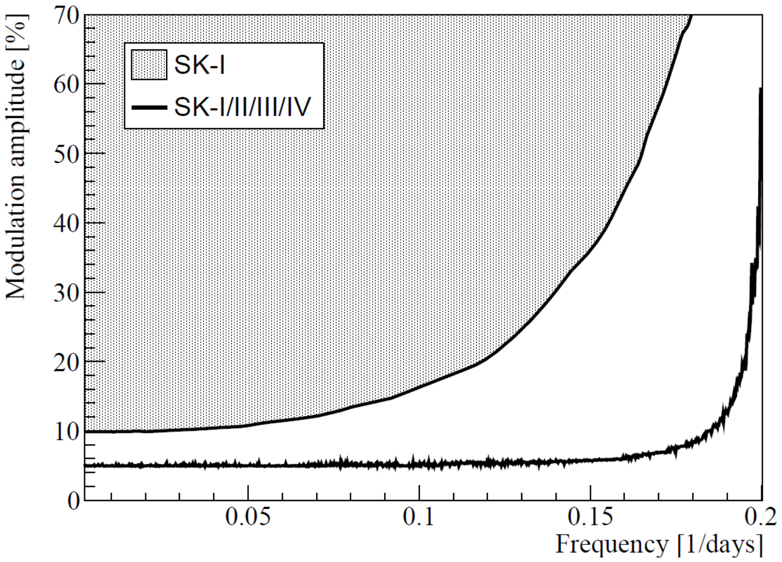
SK+SNO $\Delta m^2_{21} = 6.10^{+0.96}_{-0.81} \times 10^{-5}\ \mathrm{eV}^2$, a $\sim 1.4\sigma$ tension with KamLAND

SK I-IV Solar Neutrino Time Variation

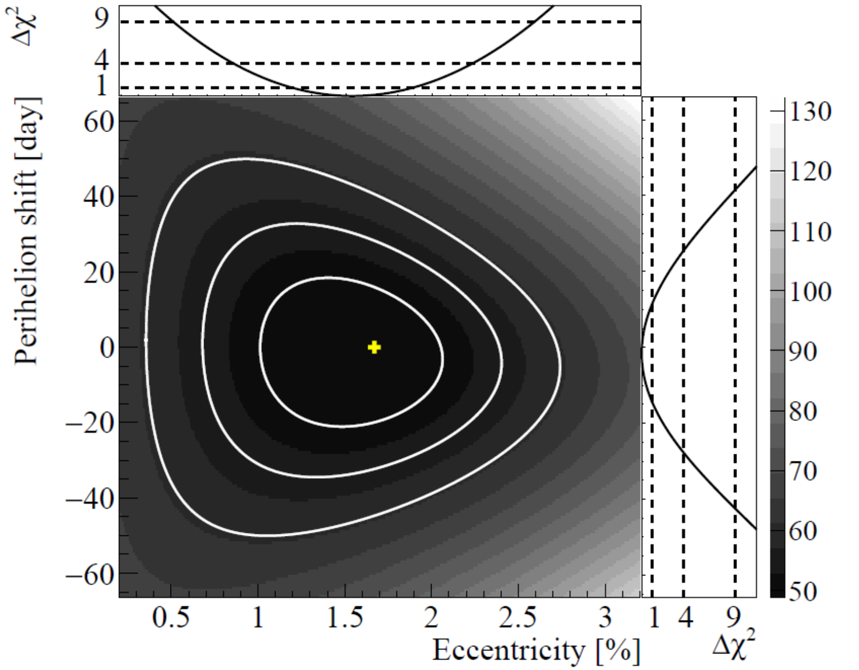
SK I-IV PRL 132, 241803 (2024)



time distribution of solar neutrino flux



95% C.L. exclusion limits on periodic variation



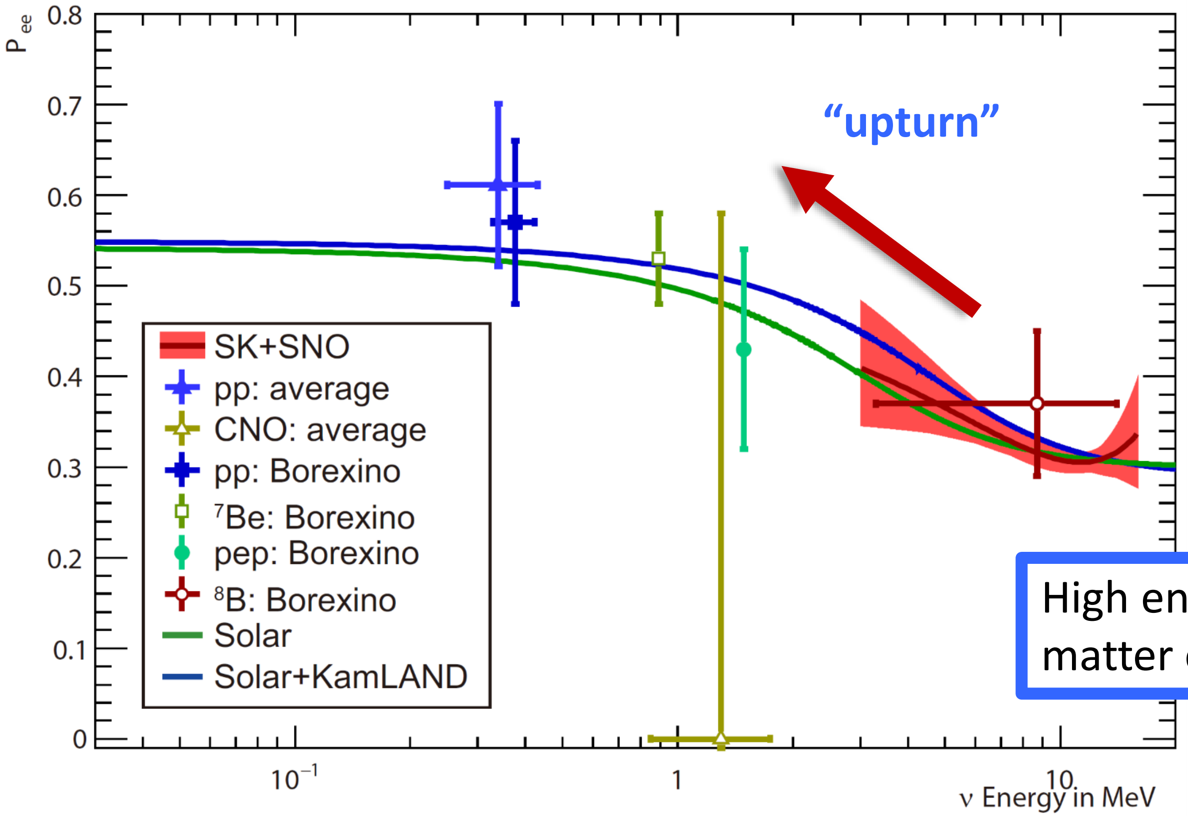
Measurement of precession and eccentricity

No significant periodic variation of ^{8}B solar ν flux

(except for seasonal variation due to the elliptic orbit of the Earth around the Sun)

Searching for the Solar Neutrino Upturn

Low energies:
vacuum oscillations dominate



High energies:
matter effects dominate

- Previous SK-IV analysis reached 3.49 MeV electron kinetic energy and found only weak evidence for the upturn.
- We studied to extend the threshold below 3.49 MeV

Improved Non-solar Background Rejection

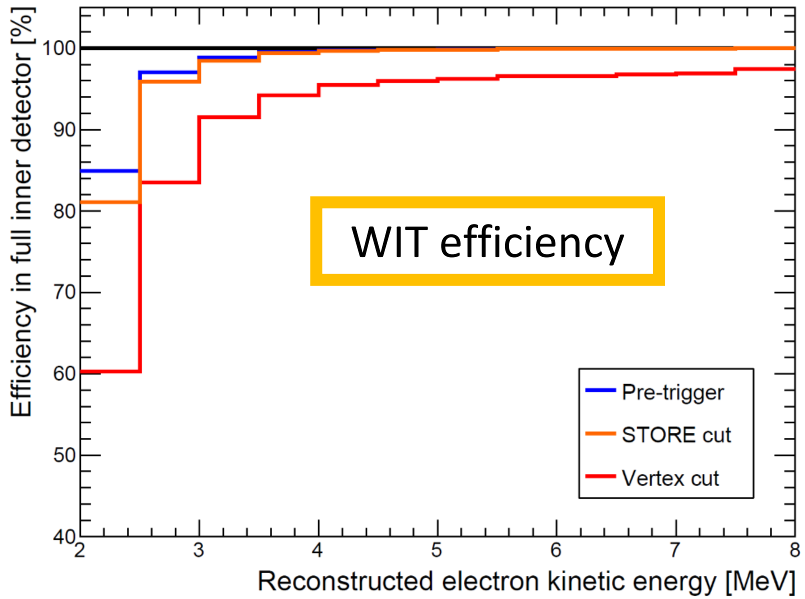
SK IV PRD 113 (11), 112001 (2026)

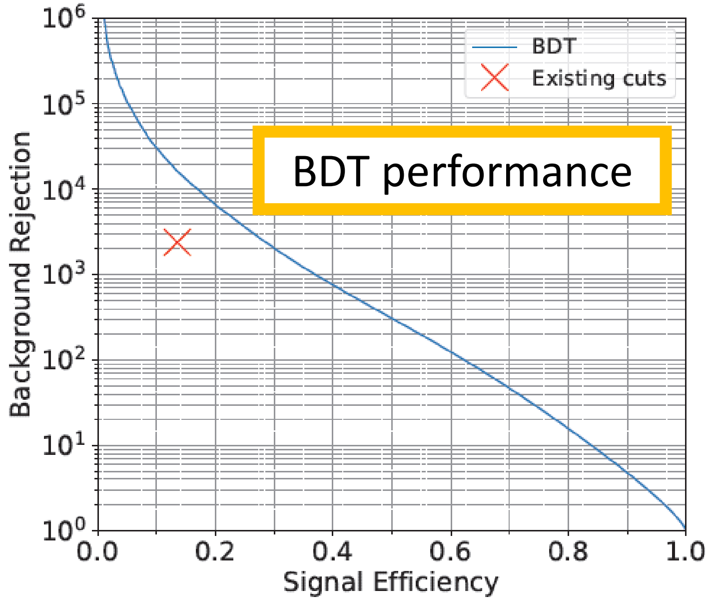
Challenge:
- radioactive background increases exponentially
- ^{214}Bi and ^{208}Tl dominate below 3.49 MeV
- signal-to-background ratio $\mathcal{O}(10^{-6})$

Existing cuts are not sufficient

Solution:
- use **Wideband Intelligent Trigger (WIT)** with lower threshold
- adopt a **Boosted Decision Tree (BDT)** selection
  - trained on solar MC as signal + real data as background

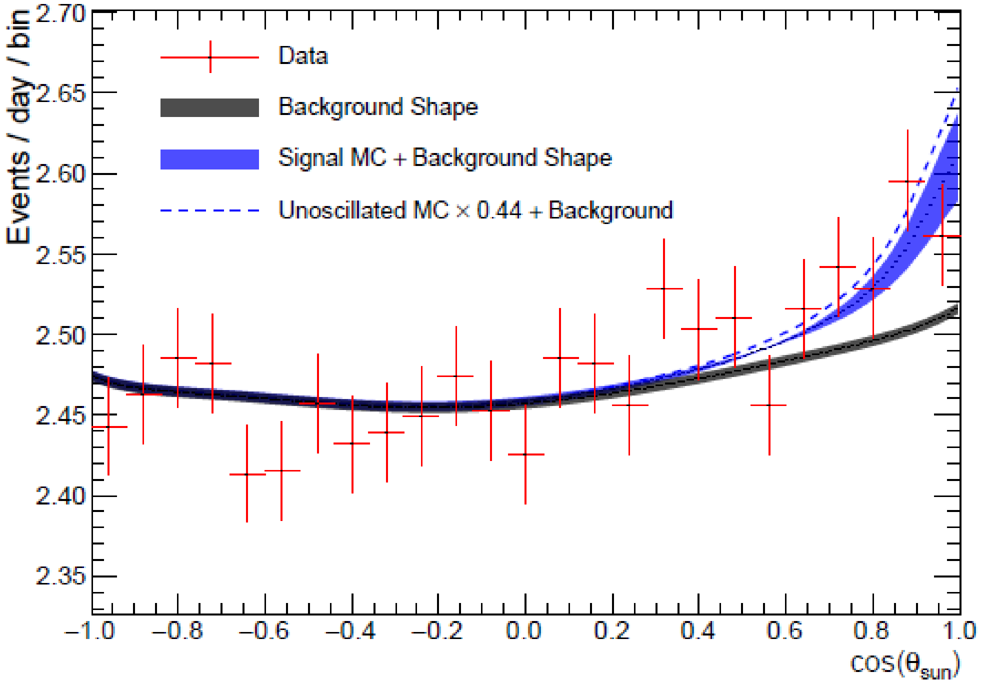
Similar signal efficiency with 6.8x better background rejection



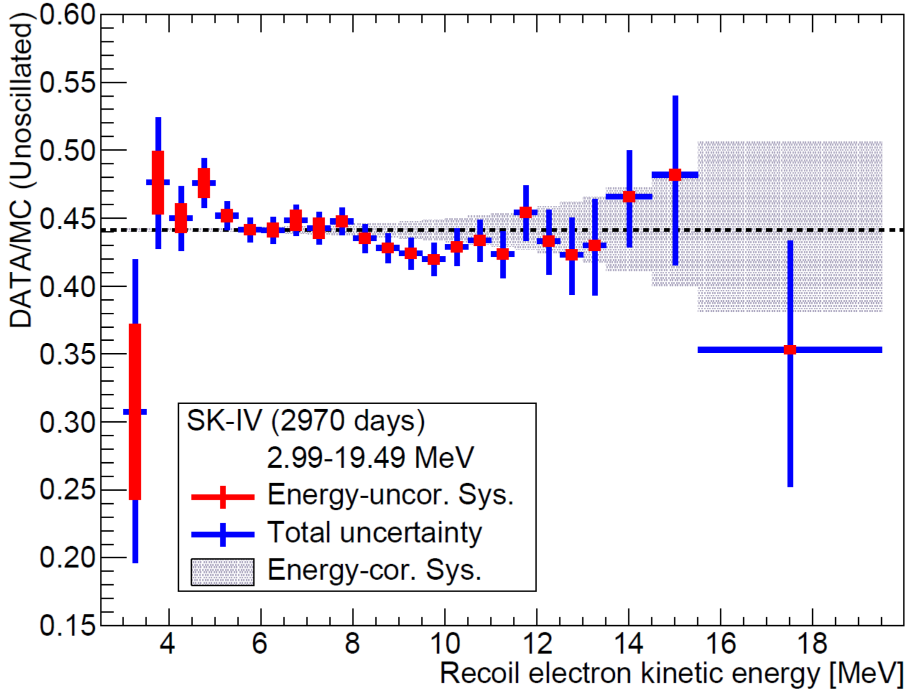


SK IV Solar Neutrinos between 2.99-3.49 MeV

Fit data solar angle distribution to extract signal
- signal template from solar MC
- background template from data



SK IV PRD 113 (11), 112001 (2026)



- Observed 667 events in 2.99-3.49 MeV at 2.76σ
- Data/MC$_{unosc}$ = $0.307^{+0.091}_{-0.090}(\text{stat.}) \pm 0.066(\text{syst.})$
- Extends the SK IV solar recoil-e spectrum to low energies
- Current uncertainties too large to measure upturn