Daya Bay final results with open data and model

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on behalf of the Daya Bay Collaboration

Joint Institute for Nuclear Research
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Plan

1. Introduction
   - Why open dataset/model
2. Daya Bay Reactor Neutrino Experiment
   - Oscillations, etc.
   - Experimental setup
   - 3ν results and flux measurements
3. Dataset: complete and light versions
   - Overview
   - Examples of reproducing the Daya Bay results with light dataset
   - Features of the complete dataset
4. Summary

Introduction

Why open dataset/model

- Publications usually do not provide a full description of model and obtained results
  - Often, we digitize observations from plots
  - Sometimes we have access to official „χ^2-maps“, „observed spectrum“, etc.
- If we want to do high precision measurements, we may need
  - > Access to the data of other experiments
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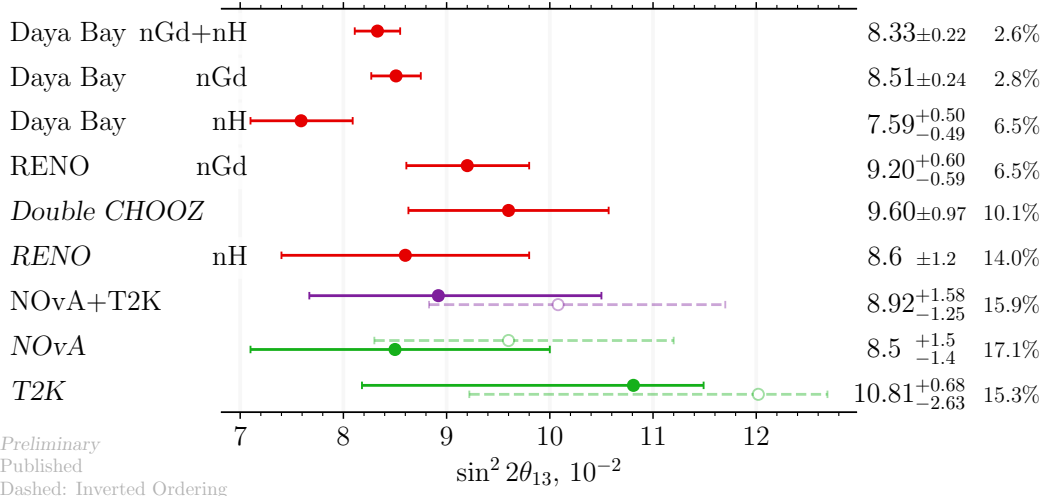
- Open dataset and model can solve issues above
  - \+ Full model allows to obtain precise results
  - \+ Correlated systematics will be propagated correctly
  - \- Implementation should have an adapter to call external models
  - \- Prelaration of open data and model might take a lot of time

Introduction

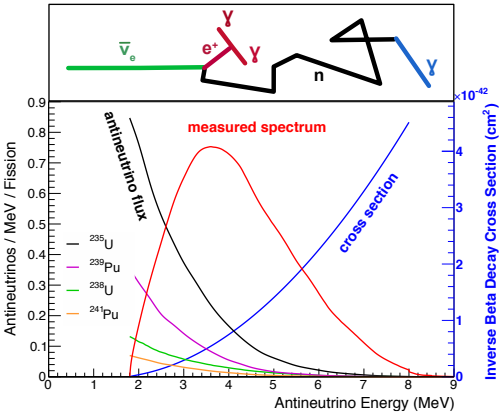
Why open dataset/model



Daya Bay Reactor Neutrino Experiment

Oscillations, etc.

- Neutrino flavor oscillates with distance
$$(\nu_{e,\mu,\tau} \rightarrow \nu_{e,\mu,\tau})$$
- Oscillation can be studied with accelerators, nuclear reactors, astrophysical sources, etc.
- Nuclear reactors are the most intense artificial source of (anti)neutrinos (10^{20} $\overline{\nu}_e$/sec/GWt)
- Energies of $\overline{\nu}_e$ is mostly below 10 MeV, it allows to measure survival probability of $\overline{\nu}_e$



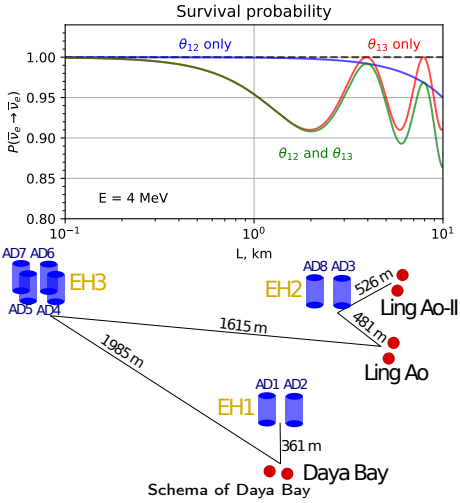
Daya Bay Reactor Neutrino Experiment

Experimental setup

- Experiment was taking data from December 2011 to December 2020
- One of the main goals is precision measurement of $\sin^2 2\theta_{13}$ and Δm^2_{32}
- Search for sterile neutrinos, high energy reactor antineutrinos ($E_\nu > 10$ MeV), measurement of ^{235}U and ^{239}Pu spectra

$$P(\overline{\nu}_e \to \overline{\nu}_e) \approx 1 - \cos^4\theta_{13}\sin^2 2\theta_{12}\left(\frac{\Delta m^2_{21} L}{4E}\right) - \sin^2 2\theta_{13}\sin^2\left(\frac{\Delta m^2_{ee} L}{4E}\right)$$

$$\Delta m^2_{ee} = \cos^2\theta_{12}\Delta m^2_{31} + \sin^2\theta_{12}\Delta m^2_{32}$$



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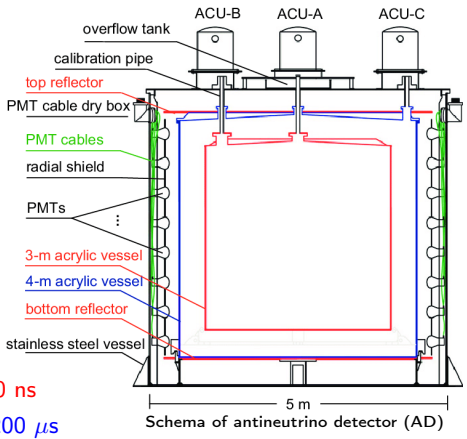


Schema of antineutrino detector (AD)

$\sigma_E/E = 8.66\%/\sqrt{E}$ [MeV]

IBD – inverse β-decay

$\overline{\nu}_e + p \to e^+ + n$ (prompt signal) $\quad \tau \simeq 80$ ns

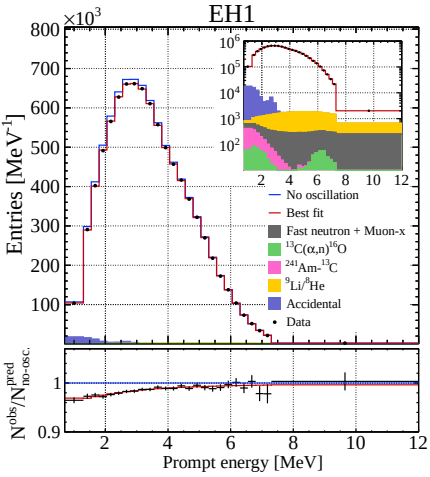
$\quad \hookrightarrow + H \to D + \gamma$ (2.2 MeV) $\quad \tau \simeq 200\ \mu$s

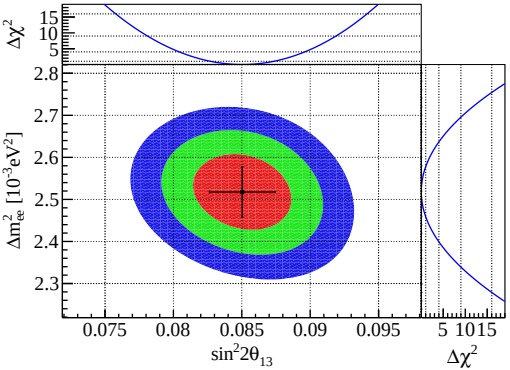
$\quad \hookrightarrow + Gd \to Gd^*$ (delayed signal)

$\quad\quad \hookrightarrow Gd + \gamma$ (8 MeV) $\quad \tau \simeq 30\ \mu$s

Daya Bay Reactor Neutrino Experiment

3ν results and flux measurements





PRL **130**, 161802 (2023)

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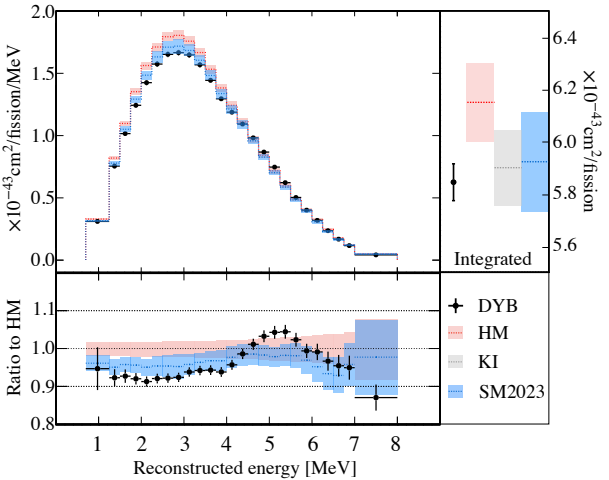

PRL **134**, 201802 (2025)

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Dataset: complete and light versions

Overview

Three periods of data taking (final-state neutron captured on gadolinium)

- 3 near + 3 far detectors: 0 – 210 days
- 4 near + 4 far detectors: 300 – 1820 days
- 3 near + 4 far detectors: 1850 – 3280 days

$\rightarrow$ 3158 days of operation

	Hall 1	Hall 2	Hall 3
Number of detectors	2	2	4
IBD candidates	2 236 810	2 544 894	764 414
ν_e rate [day^{-1}]	1342.29	1191.18	300.57
Background rate [day^{-1}]	21.93	16.20	4.47
Background / Signal ratio, %	**1.63**	**1.36**	**1.58**

- Zenodo dataset (full+light): zenodo.org/records/17587229

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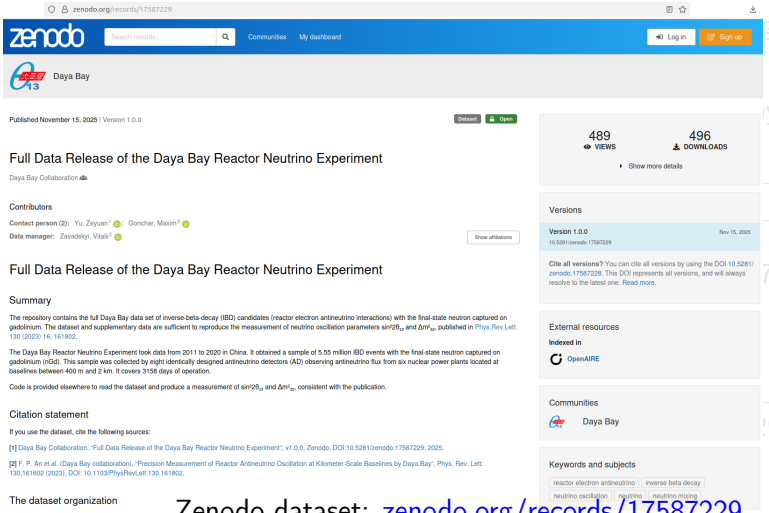

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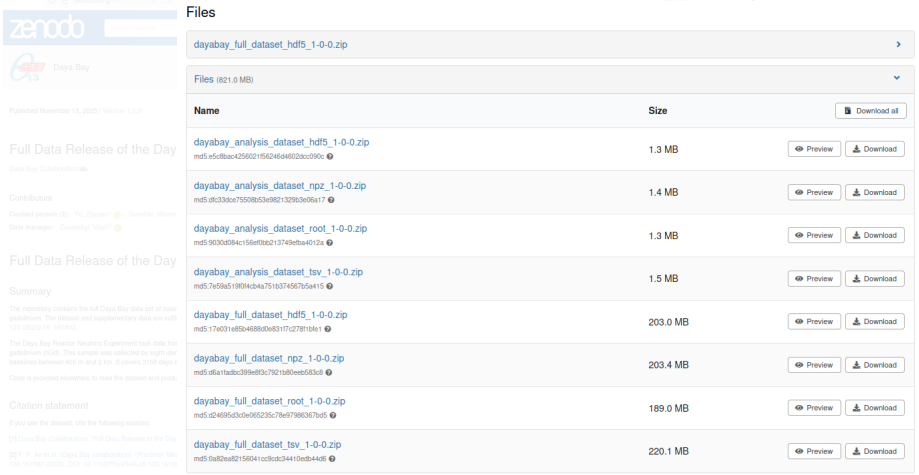

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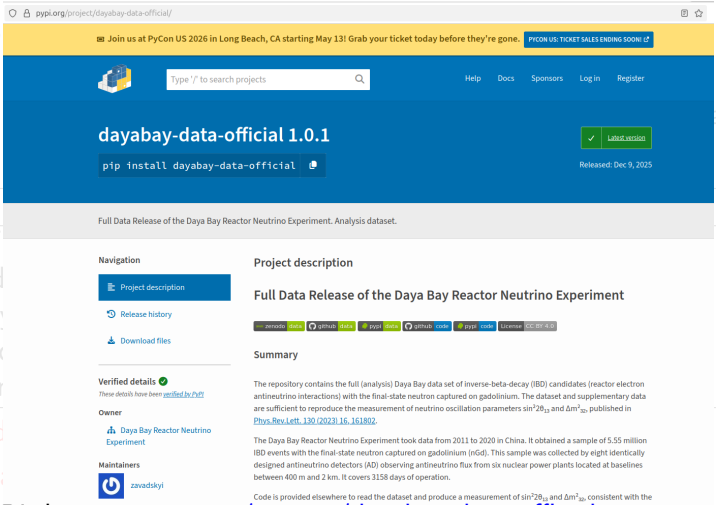

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Three periods
- 3 near +
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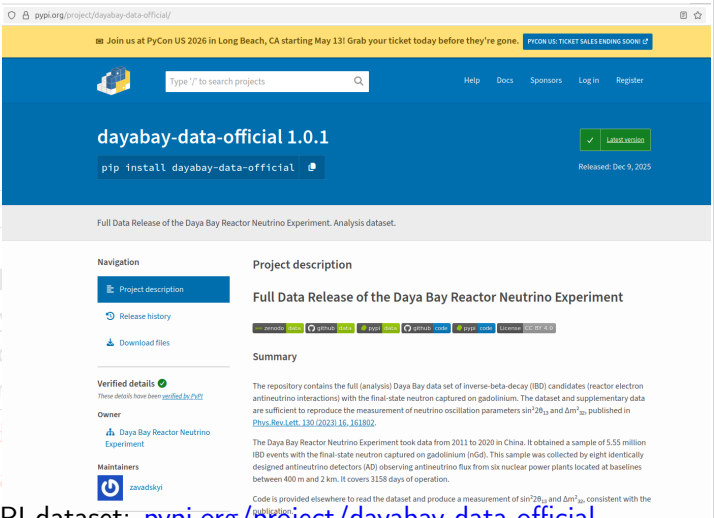


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├── dataset_info.yaml
├── dayabay_dataset
│   ├── dayabay_background_rates.hdf5
│   ├── dayabay_background_spectra_6AD.hdf5
│   ├── dayabay_background_spectra_7AD.hdf5
│   ├── dayabay_background_spectra_8AD.hdf5
│   ├── dayabay_daily_detector_data.hdf5
│   ├── dayabay_ibd_spectra_6AD.hdf5
│   ├── dayabay_ibd_spectra_7AD.hdf5
│   ├── dayabay_ibd_spectra_8AD.hdf5
│   └── dayabay_ibd_spectra_total.hdf5
├── detector_iav_matrix.hdf5
├── detector_lsnl_curves.hdf5
├── neutrino_rate.hdf5
├── nonequilibrium_correction.hdf5
├── parameters
│   ├── antineutrinos_per_fission_huber_mueller.yaml
│   ├── background_rate_scale_accidentals.yaml
│   ├── background_rates_correlated.yaml
│   ├── background_rates_uncorrelated.yaml
│   ├── background_rate_uncertainty_scale_amc.yaml
│   ├── background_rate_uncertainty_scale_site.yaml
│   ├── baselines.yaml
│   ├── conversion_survival_probability_argument.py
│   ├── conversion_thermal_power.py
│   ├── detector_efficiency.yaml
│   ├── detector_eres.yaml
│   ├── detector_iav_offdiag_scale.yaml
│   ├── detector_lsnl.yaml
│   ├── detector_normalization.yaml
│   ├── detector_n_protons_correctyam.yaml
│   ├── detector_n_protons_nominal.yaml
│   ├── detector_relative.yaml
│   ├── extra
│   │   └── detector_absolute.yaml
│   ├── final_erec_bin_edges.tsv
│   ├── ibd_constants.yaml
│   ├── pdg2024.yaml
│   ├── reactor_antineutrino_spectrum_edges.tsv
│   ├── reactor_energy_per_fission.yaml
│   ├── reactor_fission_fractions_scale.yaml
│   ├── reactor_fission_fractions.yaml
│   ├── reactor_nonequilibrium_correction.yaml
│   ├── reactor_snf.yaml
│   ├── reactor_thermal_power_nominal.yaml
│   ├── reactor_thermal_power_uncertainty.yaml
│   ├── survival_probability_constants.yaml
│   ├── survival_probability_solar.yaml
│   └── survival_probability.yaml
├── reactor_antineutrino_spectra_hm.hdf5
├── reactor_antineutrino_spectra_hm_uncertainties.hdf5
├── README_dataset.md
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└── snf_correction.hdf5
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Dataset: complete and light versions

Examples of reproducing the Daya Bay results with light dataset

- Following slides demonstrate posibility to obtain oscillation results and features of spectrum measurements
- We used light dataset to produce results
- Results were obtained with open model and they are in a good agreement with official

Dataset: complete and light versions

Examples of reproducing the Daya Bay results with light dataset

- Light dataset is sufficient for oscillation analysis
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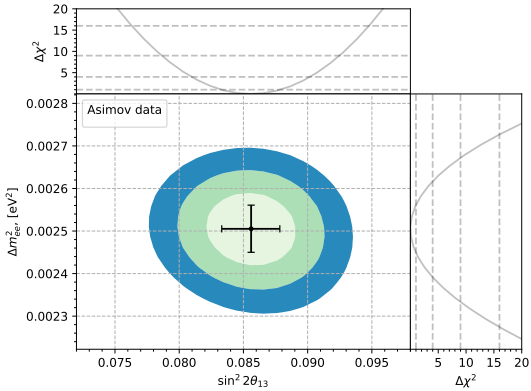

$$|(\Delta m^2_{ee})^{\text{official}} - (\Delta m^2_{ee})^{\text{obtained}}| / (\sigma(\Delta m^2_{ee})^{\text{official}}) < 0.1$$

$$|(\sin^2 2\theta_{13})^{\text{official}} - (\sin^2 2\theta_{13})^{\text{obtained}}| / (\sigma(\sin^2 2\theta_{13})^{\text{official}}) < 0.1$$

Obtained with `dayabay-model`

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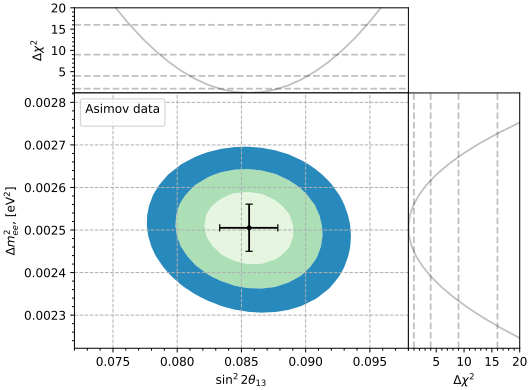

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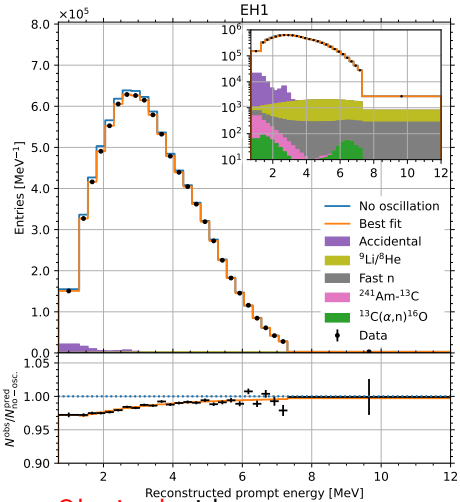
- Spectrum script: github:dagflow-team/dayabay-analysis/scripts/plot_dayabay_fit_spectrum.sh



Obtained with dayabay-model

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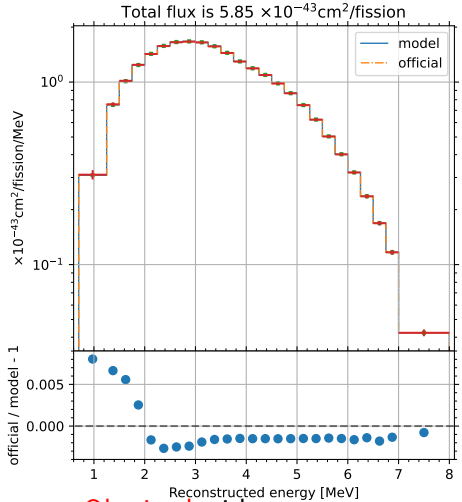
Dataset: complete and light versions

Examples of reproducing the Daya Bay results with light dataset

- Reproduces PRL **134**, 201802 (2025)
  - $\sigma_f = [5.84 \pm 0.07] \times 10^{43}\text{cm}^2/\text{fission}$



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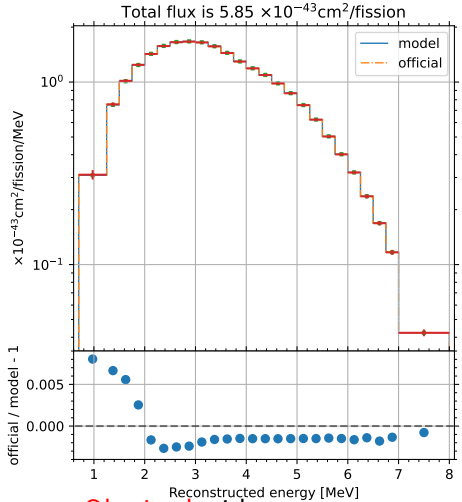
- Spectrum script: github:dagflow-team/dayabay-analysis-extra/scripts/prl_134_201802.sh



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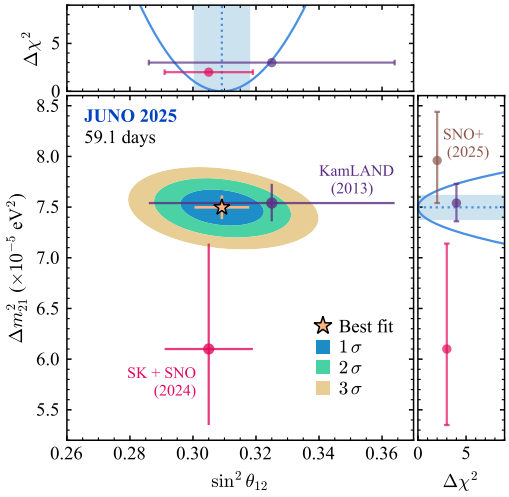
- Combined analysis with other experiments: JUNO, arXiv:2511.14593
  - > Dmitry's morning talk
  - > Presented model may be auxiliary to obtaining first oscillation measurements of JUNO



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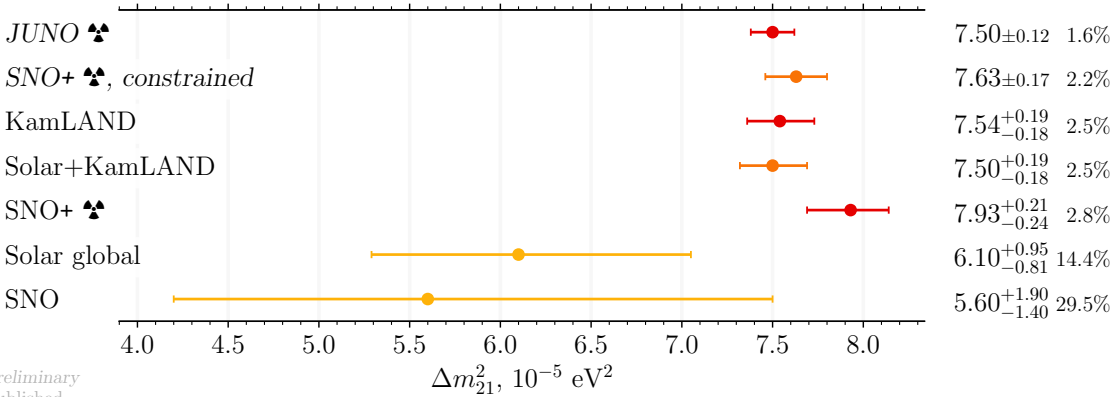

v9 2025.11: git.jinr.ru/nu/osc

First measurement of reactor neutrino oscillations at JUNO, arXiv:2511.14593

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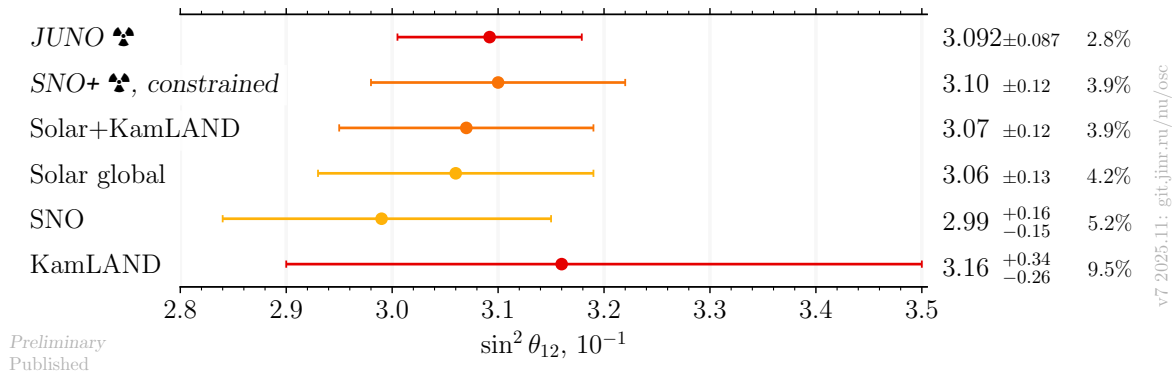

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Dataset: complete and light versions

Features of the complete dataset

- Complete tree of events in each detector: `dayabay_dataset/dayabay_events_AD??.*`

	time_prompt_s	day	n_det	energy_prompt_MeV	energy_delayed_MeV	delta_t_us	vertex_prompt_x_mm	vertex_prompt_y_mm	vertex_prompt_z_mm	vertex_delayed_x_mm	vertex_delayed_y_mm	vertex_delayed_z_mm
0	1324738631	0	6	4.39337	7.83360	21.875000	517.856818	-1408.620000	-33.650303	354.155975	-1100.270020	-93.051796
1	1324738749	0	6	3.81000	7.86787	18.775000	-939.942017	484.862000	234.387087	-955.195087	579.851990	187.132996
2	1324738785	0	6	4.72838	8.46890	14.425000	-1235.020020	770.802002	-929.328979	-1275.489990	382.811005	-1020.560000
3	1324738845	0	6	2.87176	7.85049	10.225000	-729.486982	862.734009	720.264954	-686.479004	898.222961	373.878003
4	1324738994	0	6	3.65298	7.75185	19.636999	357.983002	-985.446003	727.158997	334.113007	-988.519043	729.554016
5	1324739077	0	6	4.20659	8.75522	17.462999	1052.899900	629.765991	690.513000	735.341003	677.593970	857.895020
6	1324739099	0	6	4.62233	8.88920	25.938000	-350.788008	1019.109990	-499.597015	-382.329987	897.498051	-625.255005
7	1324739240	0	6	3.64674	8.09229	12.225000	-383.776001	-843.352966	756.026978	-398.882002	-476.814972	849.666016
8	1324739324	0	6	3.71787	8.23607	6.350000	-256.671021	508.938019	-438.725006	-30.413801	493.285017	-519.990051
9	1324739484	0	6	2.29688	7.62999	88.987999	-1162.479980	-917.110046	1849.710080	-1189.370080	-991.580080	867.519958
10	1324739724	0	6	4.74218	8.71548	47.562000	-1037.829960	-143.820007	1220.770020	-1144.880000	-198.887084	1102.489990
11	1324740177	0	6	2.27398	8.07145	18.900000	-181.634003	-927.519958	-231.612991	-15.152300	-1014.600050	-172.507996
12	1324740334	0	6	2.45659	8.05936	6.400000	793.784956	885.320007	69.171799	857.210010	1147.860060	-663.834973
13	1324740561	0	6	4.38522	6.94963	22.438000	-186.188995	1246.160030	-442.225983	-184.268997	1375.470090	-239.392990
14	1324740804	0	6	5.17950	7.93842	28.375000	-562.247986	1241.410030	993.145020	-668.976013	1102.669920	863.887024
15	1324740815	0	6	1.40974	6.42094	52.450001	864.442017	179.578999	-743.948975	1368.219970	-113.829002	-64.613502
16	1324740972	0	6	4.55045	7.64849	129.850003	-980.921997	-496.605011	61.985781	-786.418030	-626.115051	-39.269501
17	1324741196	0	6	3.57428	8.26961	24.862000	733.659973	-303.387087	161.494003	1156.469978	-416.896008	-255.284012
18	1324741212	0	6	3.21946	7.71839	35.875000	991.835022	-715.786011	-491.725006	1166.828078	-610.286011	-314.162994
19	1324741585	0	6	2.61112	8.04346	16.188000	534.786011	200.266086	-1488.750000	692.338989	89.210693	-1034.350100

- Possible to reproduce prompt signal at any step
  - > Search for high energy $\overline{\nu}_e$s
  - > Directionality of neutrino flux
- Time/position information might be used for searching anomalies, light dark matter, BSM, etc.

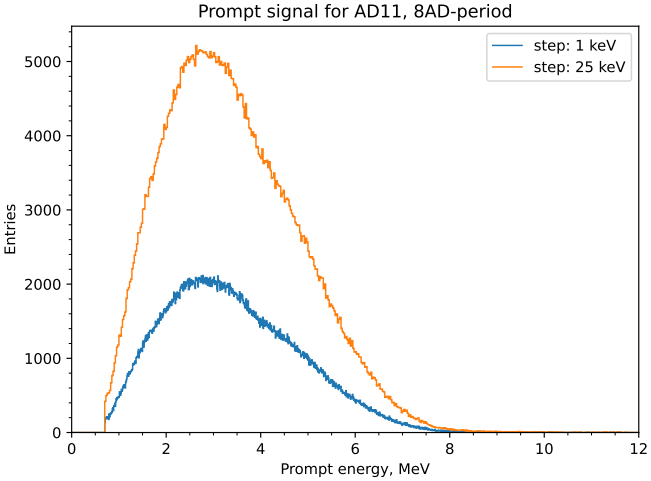
Dataset: complete and light versions

Features of the complete dataset

- Complete tree of events in each de

	time_prompt_s	day	n_det	energy_prompt_MeV	energy_delayed_MeV	delta_t_
0	1324738631	0	6	4.39337	7.83368	21.875(
1	1324738749	0	6	3.81808	7.86787	18.775(
2	1324738785	0	6	4.72838	8.46898	14.425(
3	1324738845	0	6	2.97176	7.85849	10.225(
4	1324738994	0	6	3.65270	7.95145	19.434(
5	1324739077	0	6	4.28659	8.75522	17.462(
6	1324739099	0	6	4.62233	8.98928	25.938(
7	1324739240	0	6	3.64674	8.09229	12.225(
8	1324739324	0	6	3.71787	8.25687	6.358(
9	1324739484	0	6	2.29688	7.62999	88.987(
10	1324739724	0	6	4.74218	8.71548	47.562(
11	1324748177	0	6	2.27396	8.07145	18.908(
12	1324748554	0	6	2.45659	8.05934	4.408(
13	1324748561	0	6	4.38522	6.94963	22.438(
14	1324748884	0	6	5.17958	7.93842	28.375(
15	1324748815	0	6	1.40976	6.42894	52.658(
16	1324748972	0	6	4.55845	7.64849	129.858(
17	1324741196	0	6	3.57428	8.26961	24.862(
18	1324741212	0	6	3.21944	7.71859	35.875(
19	1324741988	0	6	2.61112	8.04546	16.188(

- Possible to reproduce prompt signa
  - > Search for high energy $\overline{\nu}_e$s
  - > Directionality of neutrino flux
- Time/position information might b BSM, etc.



Summary

- Open Daya Bay dataset and model were published
  - \+ Good agreement with official results
  - \> Dataset: zenodo, PyPI, github
  - \> Model: PyPI, github, gitlab@JINR
  - \> Examples: github-1, github-2, gitlab-1@JINR, gitlab-2@JINR
  - \> Citations: DOI:10.5281/zenodo.17587229; DOI: 10.1103/PhysRevLett.130.161802
- Reproduction of key results of last years were shown
- Possibility of search for BSM, combined analysis with other experiments

Blue links are clickable

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Thank you for attention!

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