GLoBES Installation Guide & Example

A Global Analysis Tool for Neutrino Oscillation Experiments

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Outline

Neutrino Oscillation

What is Neutrino Oscillation?

Neutrinos produced in one flavor eigenstate can change to a different flavor during propagation. This phenomenon can be described by the **PMNS matrix** — a 3×3 unitary mixing matrix.

Oscillation Parameters

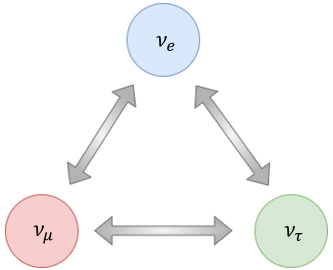
4 mixing parameters:

- θ_{12}, θ_{13}, θ_{23} — mixing angles
- δ_{CP} — phase angle

2 mass-squared differences:

- Δm^2_{21}, Δm^2_{32}

$\Rightarrow$ **6 free parameters in total**



$$U = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix} \cdot \begin{pmatrix} c_{13} & 0 & s_{13}e^{-i\delta_{\mathrm{CP}}} \\ 0 & 1 & 0 \\ -s_{13}e^{i\delta_{\mathrm{CP}}} & 0 & c_{13} \end{pmatrix} \cdot \begin{pmatrix} c_{21} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

Neutrino Oscillation

How Are These Parameters Determined?

All 6 oscillation parameters are extracted by **fitting theoretical predictions to the experimental data** (you can find the latest results in `http://www.nu-fit.org`).

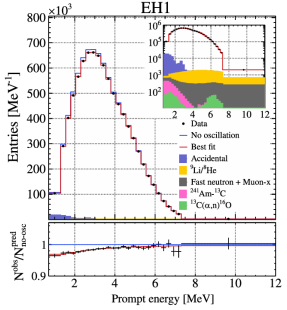


Figure: Data and fit result for DayaBay, EH1.

Neutrino Oscillation

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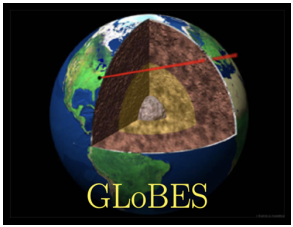
The Key Question

To judge the quality of a fit, we need a quantitative metric that measures the agreement between theory and experiment.

$$\chi^2 = \sum_i \frac{(O_i - T_i)^2}{\sigma_i^2}$$

The **chi-squared statistic** is the standard tool for this purpose.

What is GLoBES?



GLoBES (General Long Baseline Experiment Simulator) is a scientific computing library for simulating neutrino oscillation experiments. It can:

- Load experiment configurations
- Define oscillation parameters
- Simulate event rates
- Compute χ^2 values that include systematic errors

GLoBES Installation: Prerequisites

System Requirements

- Linux operating system
- C/C++ compiler (GCC)
- GNU Scientific Library (GSL)

Install Dependencies

```
sudo apt update
sudo apt install build-essential libgsl-dev
```

Installation Steps

1. Clone the repository:

```
git clone https://github.com/WeiMXi/globes-cmake.git
cd globes-cmake
```

2. Build with CMake:

```
mkdir build && cd build
cmake ..
make
```

3. Run the example:

```
cd examples
./example1
```

And you will get a data file test1.dat.

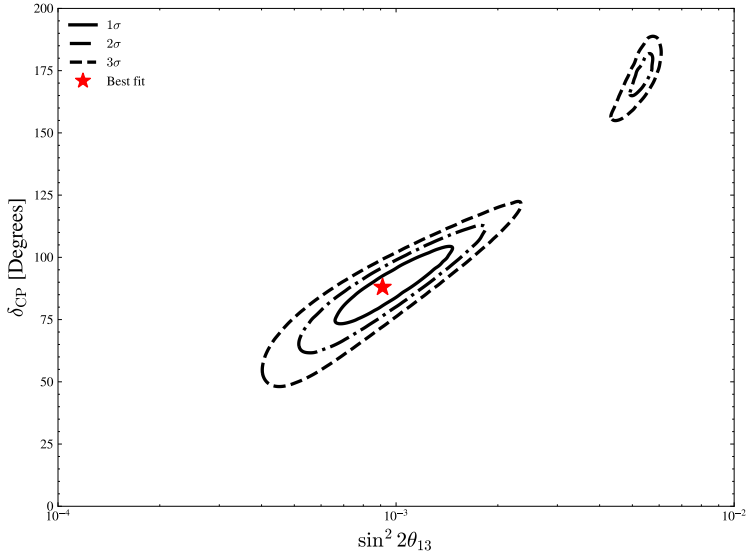
Key Elements of a Good Scientific Plot

After you generate the data, you should create plots to present your results.

A high-quality scientific figure should include

- **Legend**: symbols, line styles, and colors must match the data curves; text should be concise and unambiguous; place in an empty area within the plot;
- **Tick marks**: all four axes (top, bottom, left, right) must have tick marks; all ticks (major and minor) must point inward toward the data area;
- **Axis limits**: set appropriate ranges so that data curves occupy the main area of the figure;
- **Image format**: save as vector graphics (PDF, SVG, EPS) whenever possible.

Example Output: χ^2 Contour



Homework

Task

- Install GLoBES on your computer, compile and run example 1 successfully.
- Using Python code offered in the manual, plot the data generated by example 1 as a contour.

Submission

- A screenshot that proving you have run example 1 successfully.
- The figure generated by Python code.

Thank you!

For more information, please refer to the GLoBES User Manual
or browse our open-source repository in arxiv 2601.00790