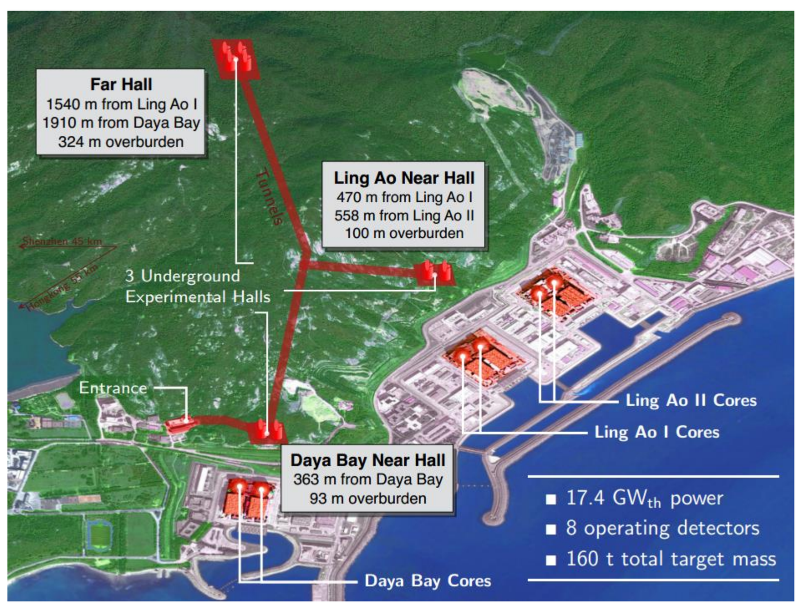
Daya Bay oscillation results with neutron capture by hydrogen

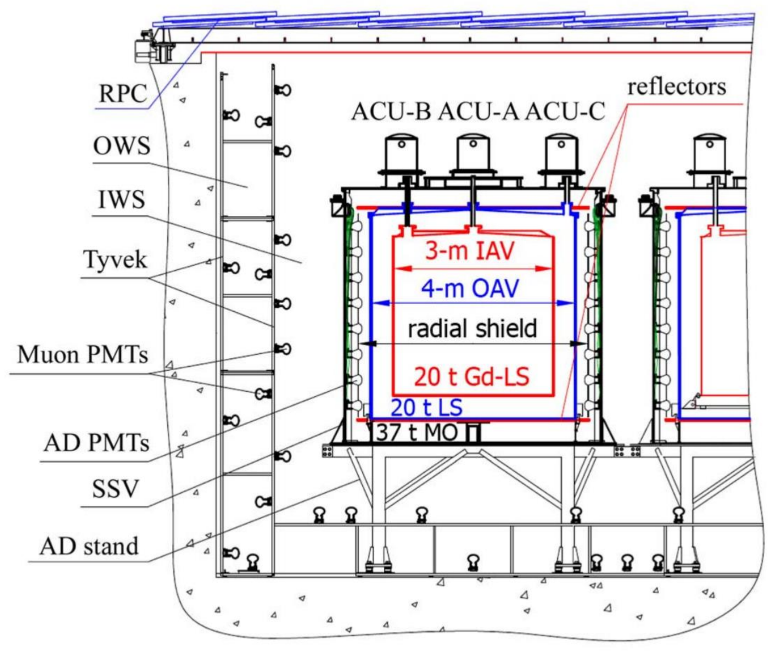
Zhiyuan Chen, Institute of High Energy Physics, Chinese Academy of Sciences, Beijing * chenzhiyuan@ihep.ac.cn
(on behalf of the Daya Bay collaboration)

Daya Bay Reactor Neutrino Experiment [1]

Daya Bay Reactor Neutrino Experiment was designed to precisely measure the neutrino mixing angle θ_{13}.

- Sources: electron antineutrinos from Daya Bay and Ling Ao reactors
- Near-far relative measurement
  - ➢ Near: monitor antineutrino flux
  - ➢ Far: measure the oscillation
- Antineutrino detector (AD):
  - ➢ Gadolinium-doped liquid scintillator (GdLS): target volume
  - ➢ Liquid scintillator (LS): catcher and target volume
  - ➢ Mineral oil (MO): radial shield
- Water pool for shielding and muon veto
- Measure θ_{13} via neutron capture on gadolinium (nGd) or hydrogen (nH)





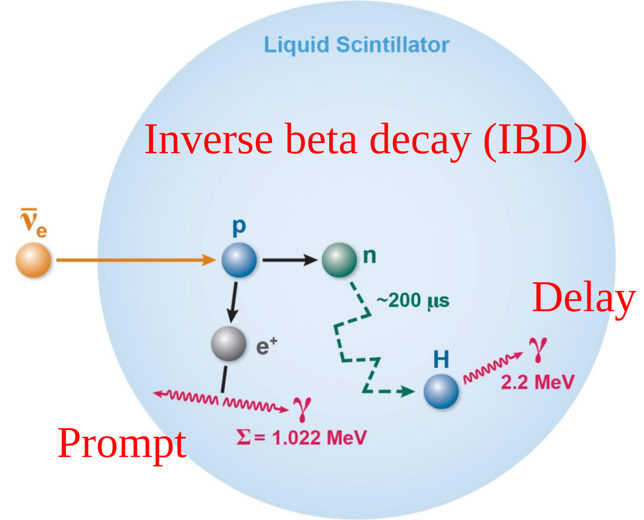
nH IBD Selection

Challenges

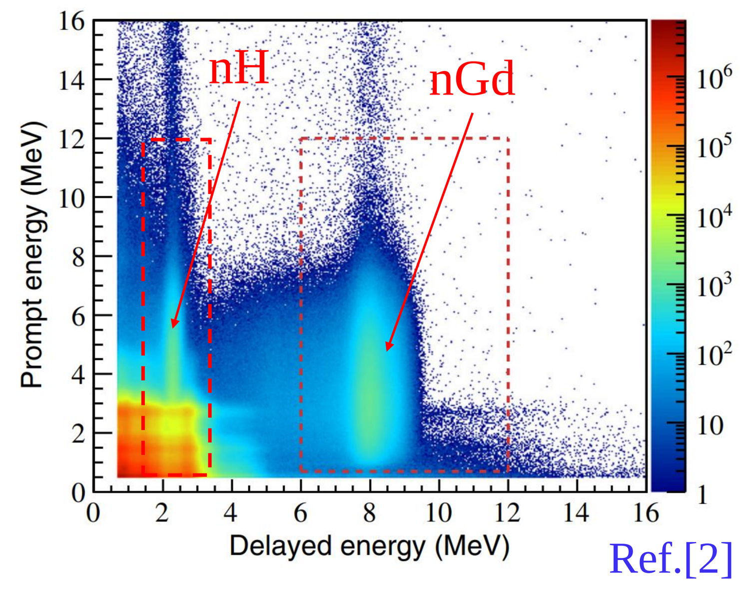
- Large accidental background
- Significant energy leak

Selection criteria

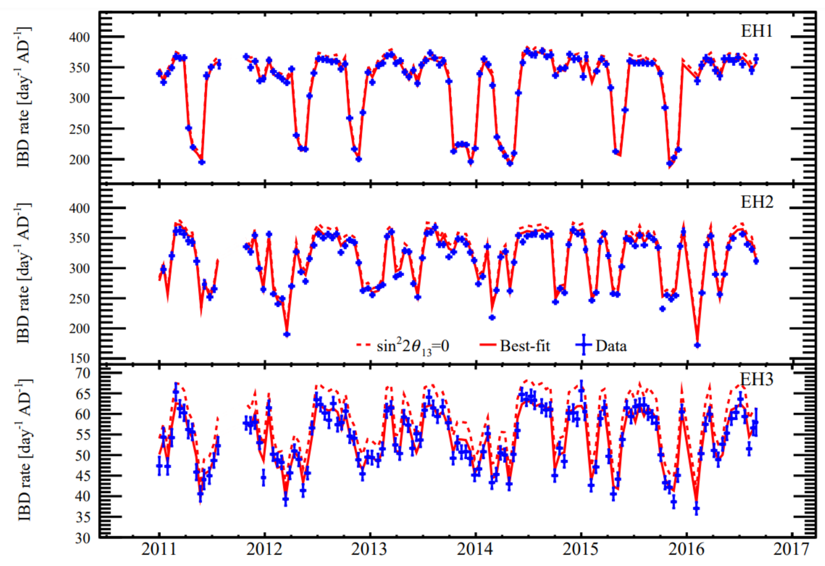
- PMT flasher cut & muon veto
- Prompt energy cut: (1.5, 12) MeV
- Delayed energy cut: (μ-3σ, μ+3σ) MeV
- Neutron capture time cut: (1, 1500) μs
- Distance-time cut: DT = *dr* + *dt*·*v* < 1 m
- Multiplicity cut



◆ μ and σ are the mean and resolution of nH delayed peak

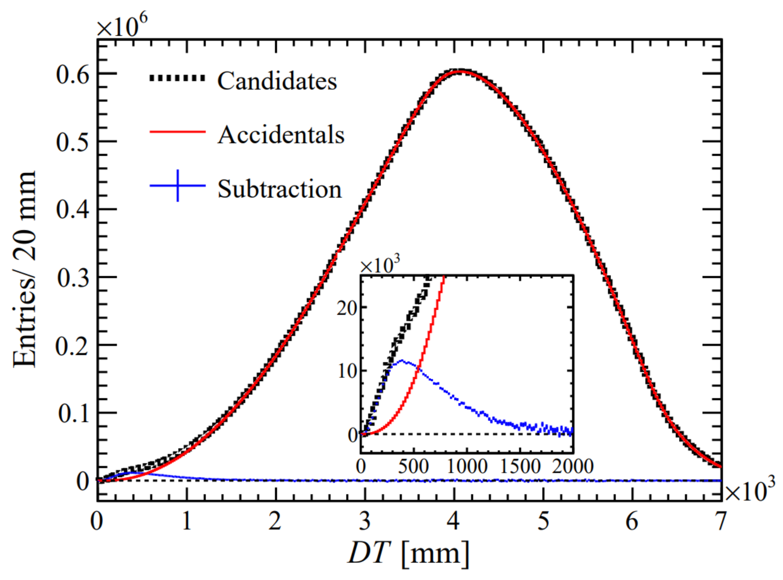


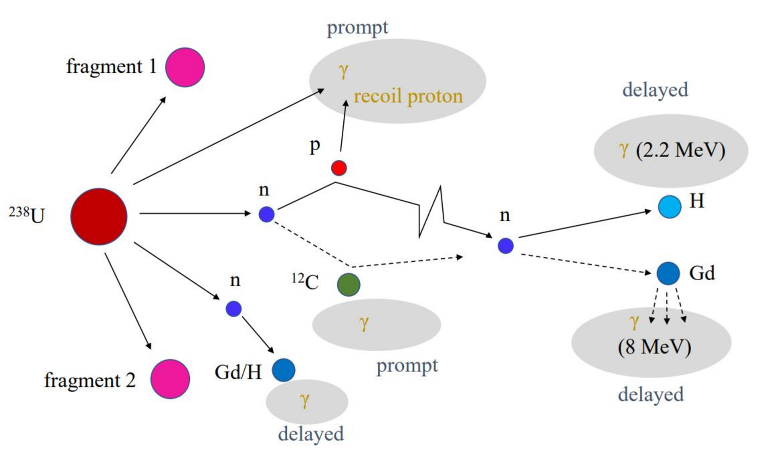
Ref.[2]

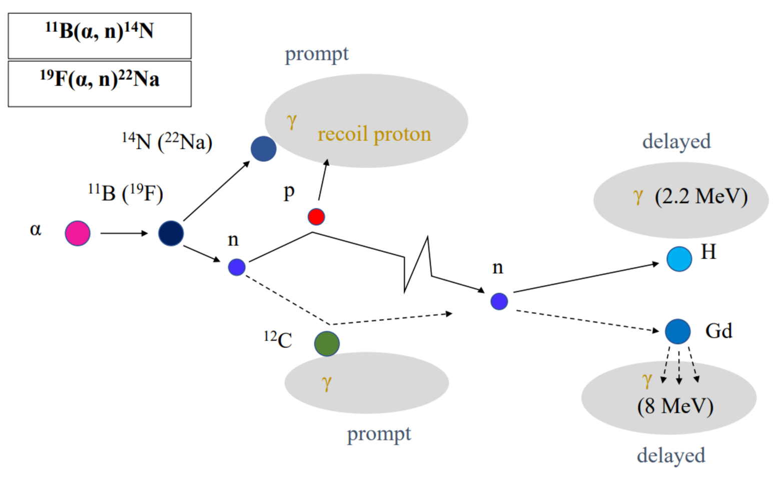


Backgrounds Analysis

- **Accidentals**: occasionally satisfied IBD criteria
  - ➢ nearly double of IBDs at far site
  - ➢ validated by distance and time distributions
- **Fast neutrons**: coincidence of fast neutron scatters and its capture





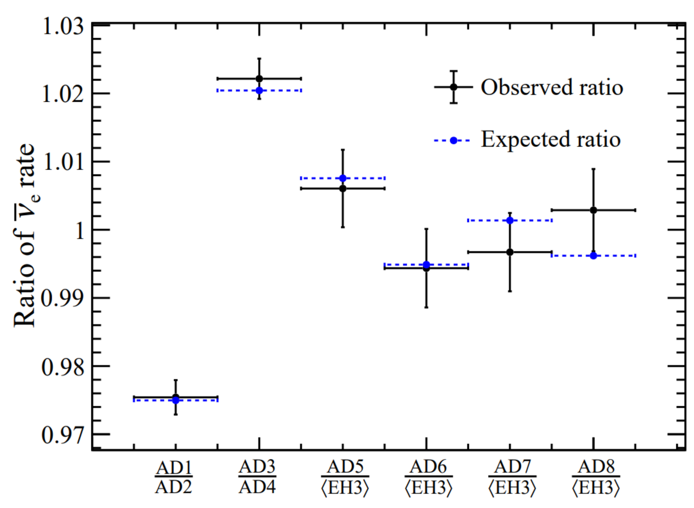


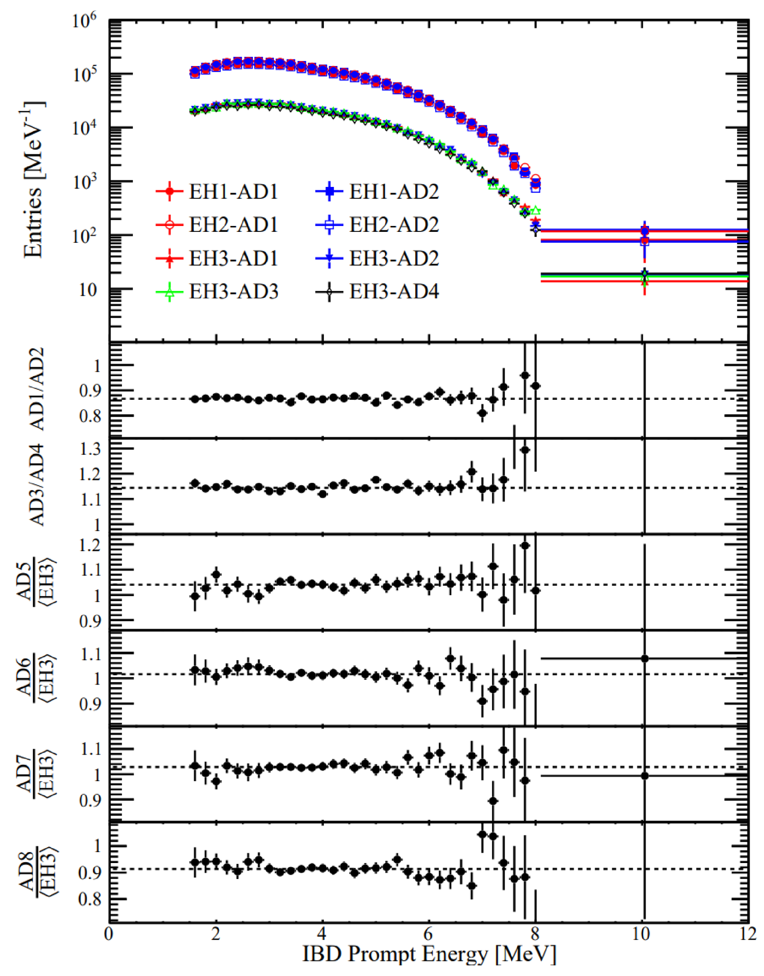
- **^{9}Li/^{8}He**: unstable nuclide from muons
- **^{241}Am-^{13}C**: neutrons from calibration source
- **Radiogenic neutron**: neutrons from peripheral materials [3]
  - ➢ Sources
    - ^{238}U spontaneous fission
    - (α,n) reaction of boron and fluorine
  - ➢ Mass ratio of boron measured with disassembled PMTs
  - ➢ Study with simulation

Uncertainty and side-by-side comparison

	Uncertainty (%)
Target protons	0.11
Prompt energy	0.13
(1, 1500) μs	0.10
Delayed energy	0.20
Coincidence DT	0.20
Combined	0.34

- Correlated uncertainties cancelled
- Uncorrelated uncertainties estimated by the variation among 8 ADs.





- Side-by-side comparison to ensure relative measurement

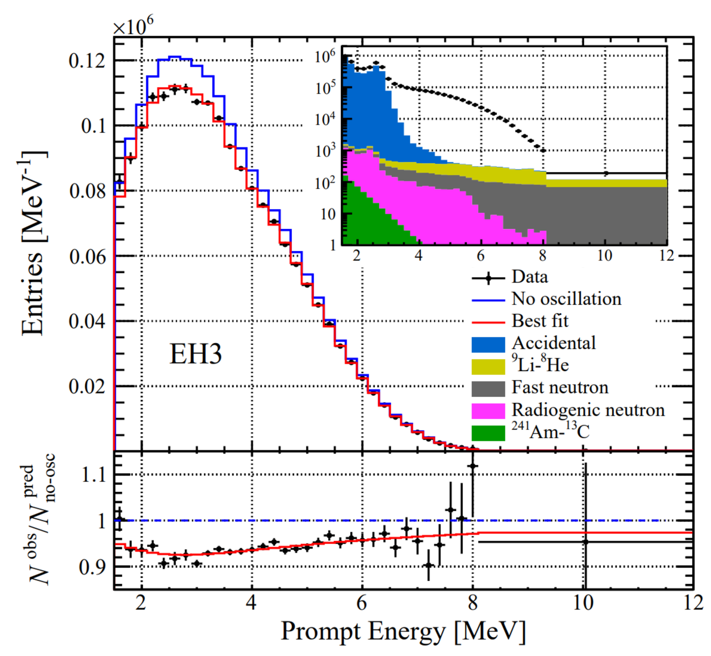
Results of Oscillation Analysis[4]

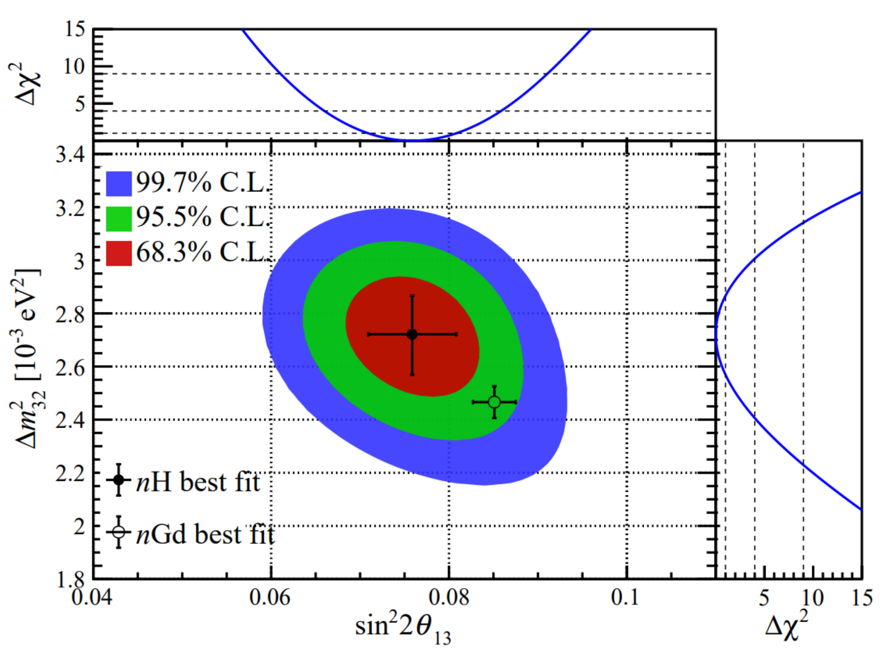
- Oscillation fitting
  - ➢ Rate-only: total deficit of IBD rate at each AD
  - ➢ Rate+shape: deficit of IBD rate at different neutrino energy range
- Two independent analysis for careful cross check
- **Using 1958-days data, consistent with nGd results (2.8% precision) [5]**

$\sin^2 2\theta_{13} = 0.0759 \pm 0.0050$
$\Delta m^2_{32} = (2.72 \pm 0.15) \times 10^{-3}\ eV^2$

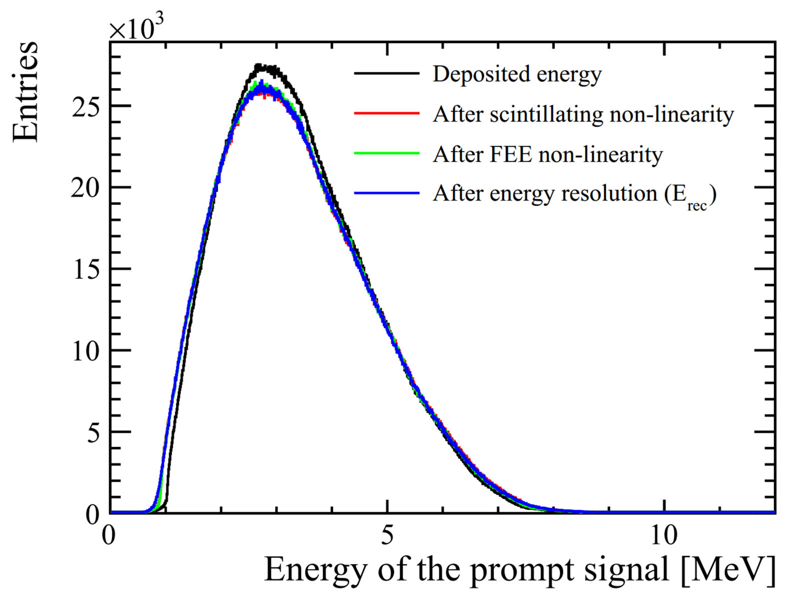
+ nGd →

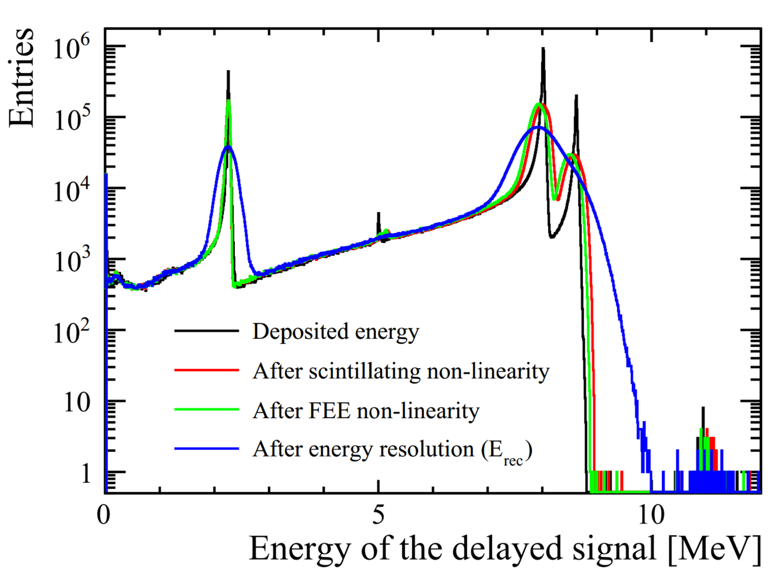
$\sin^2 2\theta_{13} = 0.0833 \pm 0.0022$
(2.6% precision)



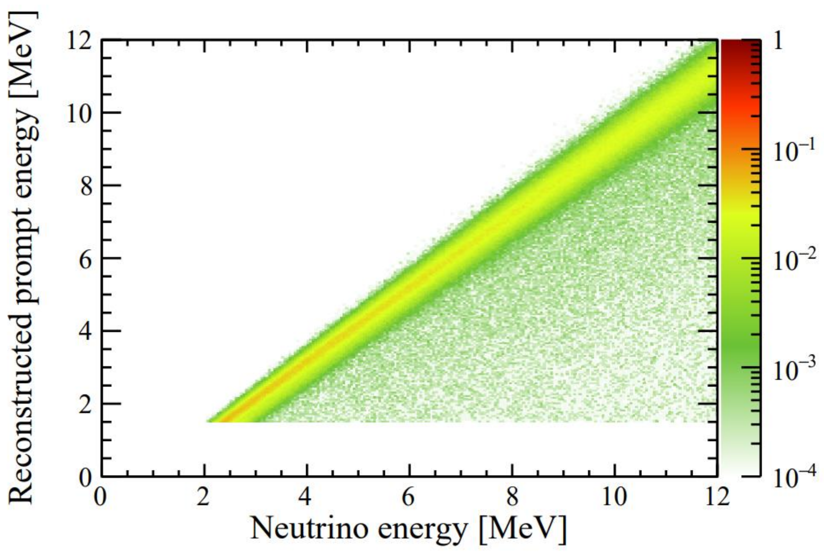


Energy Model





- Energy leak
  - ➢ Non-scintillating regions
- Energy nonlinearity
  - ➢ Liquid scintillator
  - ➢ Electronics
- Energy resolution
- Energy non-uniformity
  - ➢ Fine tuning with data



References

[1] F. P. An et al. (Daya Bay), Nucl. Instrum. Meth. A 811, 133 (2016).
[2] F. P. An et al. (Daya Bay), Phys. Rev. D 95, 072006 (2017).
[3] Z. Y. Chen et al., Phys. Rev. D 104, 092006 (2021).
[4] F. P. An et al. (Daya Bay), arXiv:2406.01007 [hep-ex] (2024).
[5] F. P. An et al. (Daya Bay), Phys. Rev. Lett. 130, 161802 (2023).

XXXI International Conference on Neutrino Physics and Astrophysics
Milano (Italy) - June 16-22, 2024

NEUTRINO 2024