The RENO Experiment: Physics Results and Ongoing Analyses

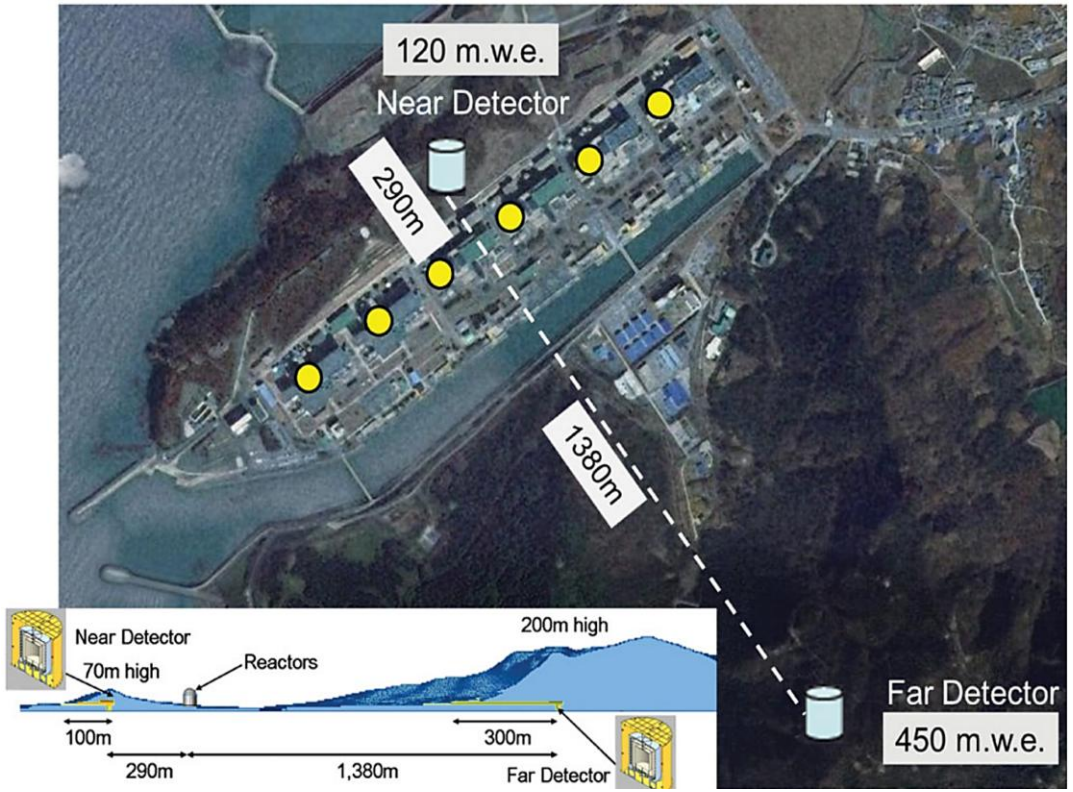
Sanghoon Jeon
for the RENO Collaboration

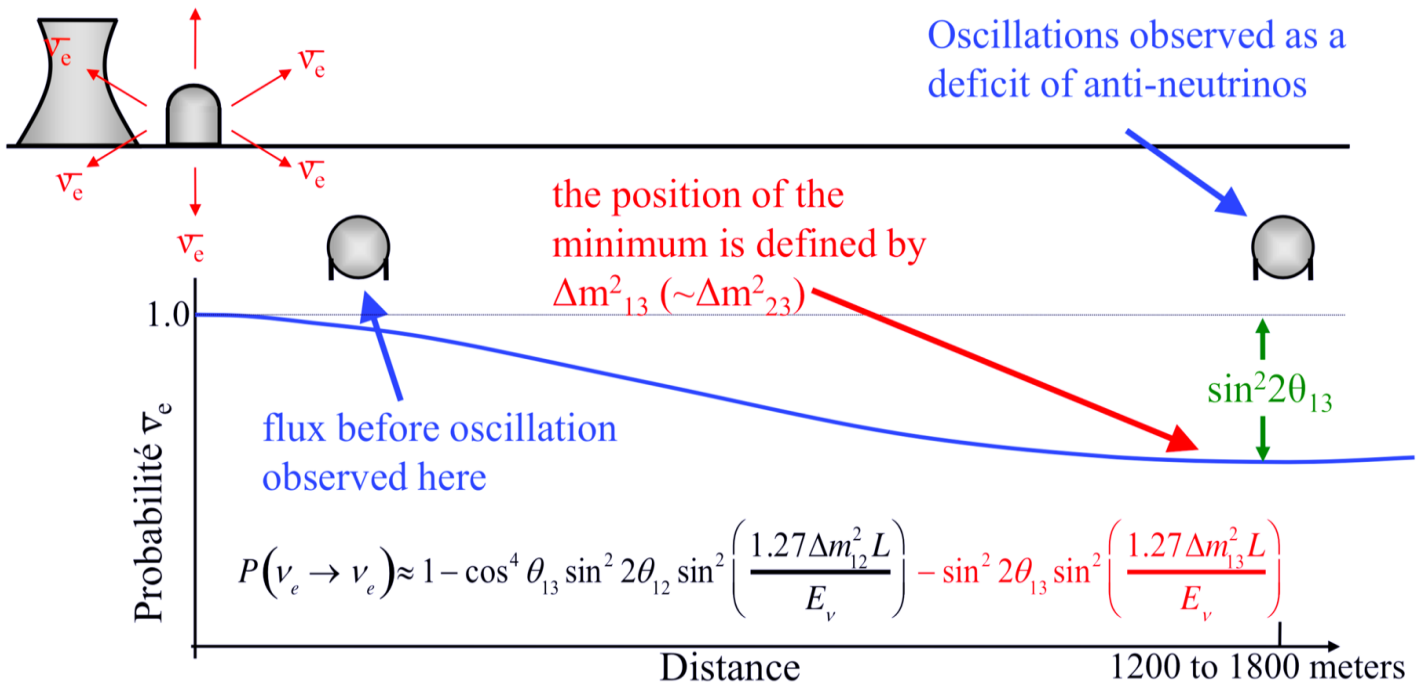
CPNR Workshop 2026
Oct. 26, 2026

RENO Experiment

Two identical detectors on different baselines

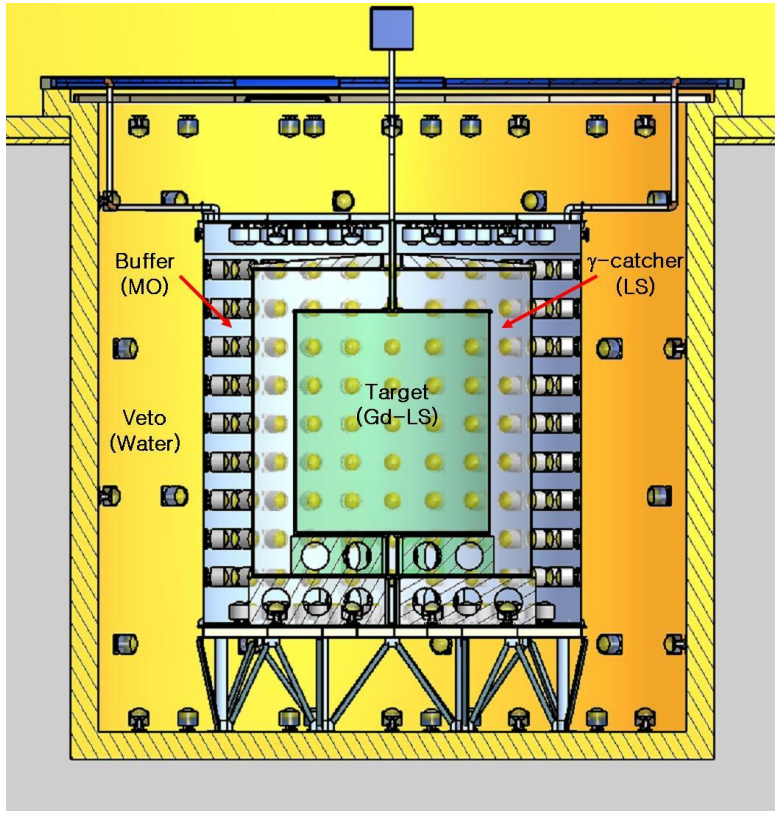
- Directly observe the oscillation induced rate deficit and spectral distortion
- Reduce the systematic uncertainty and reactor model dependence



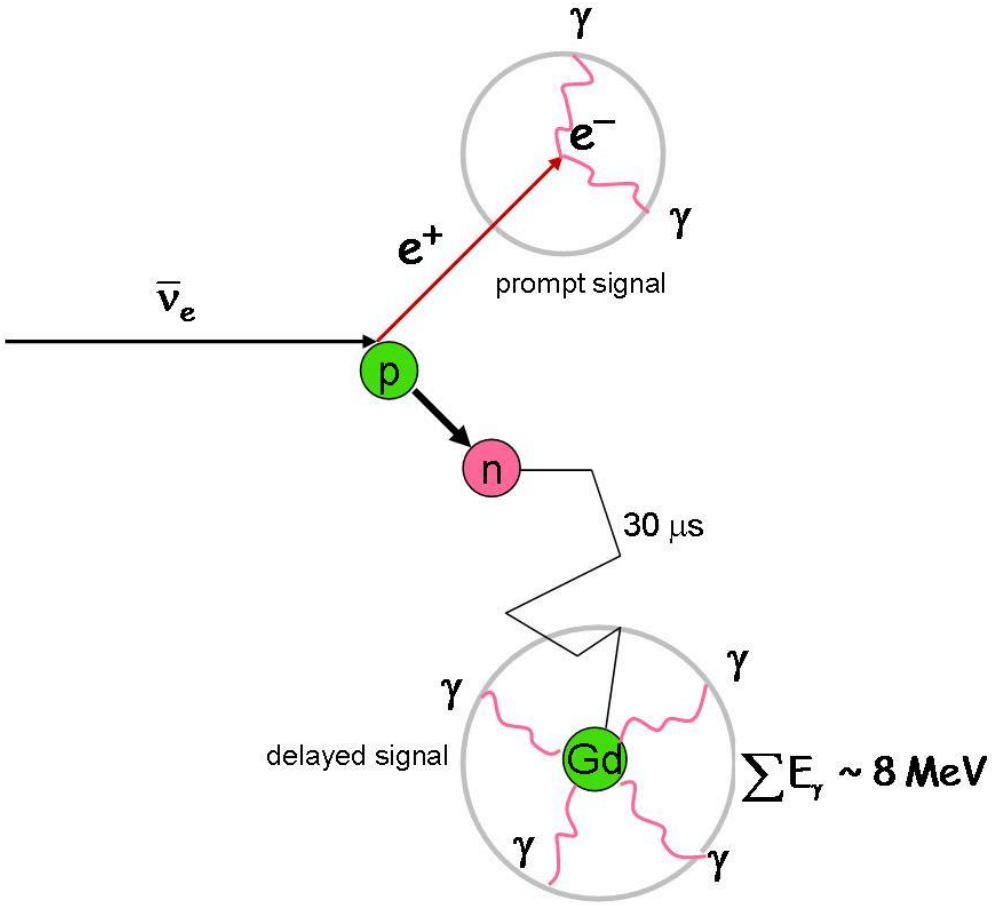


Detector & $\bar{\nu}_e$ Detection

The RENO Detectors



$\bar{\nu}_e$ detection via inverse-beta-decay

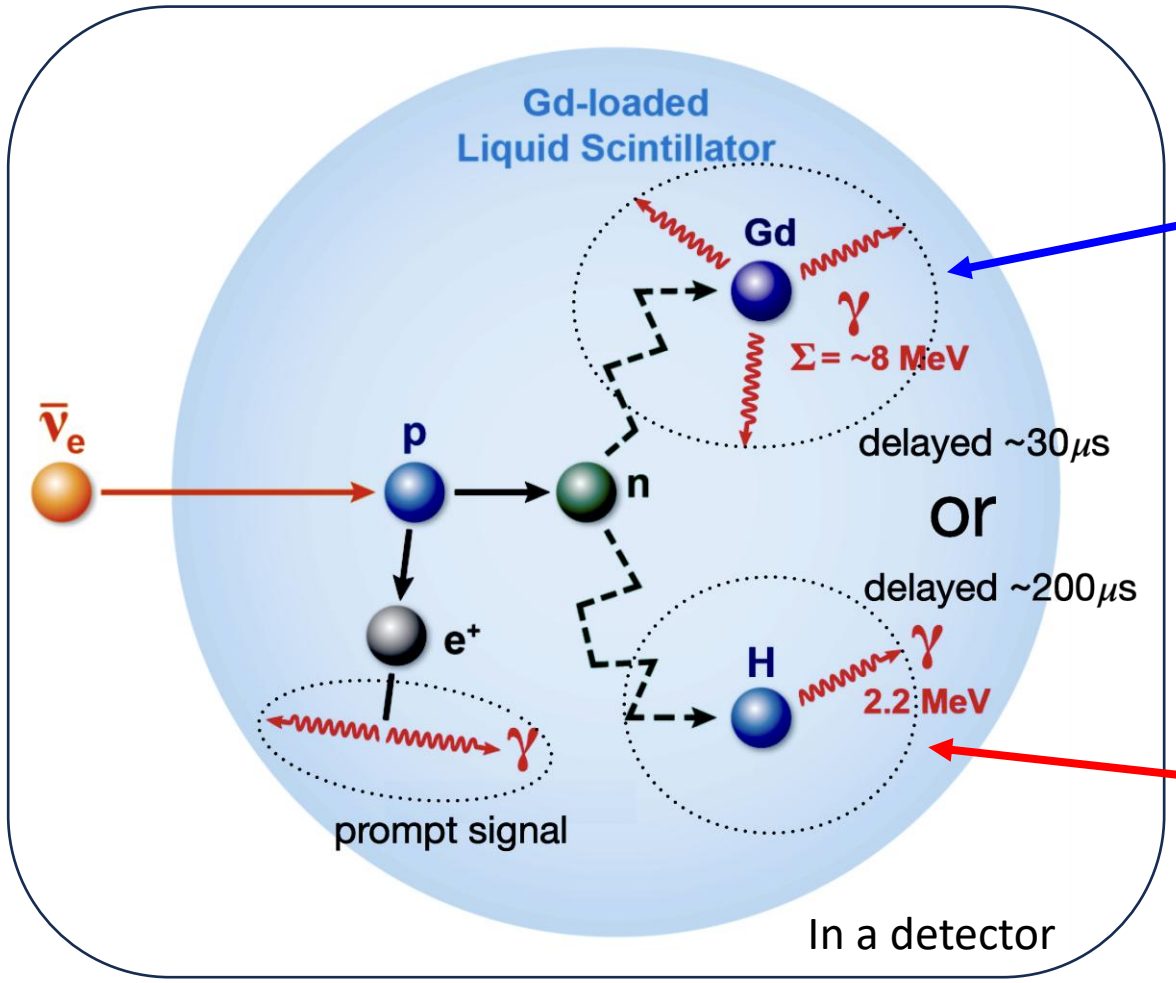


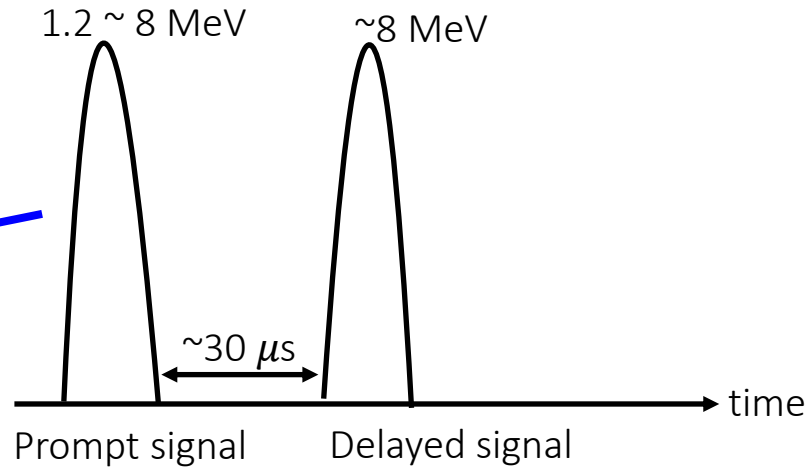
- Identical for the far & near detectors
- A multi-layered structure with different functional components

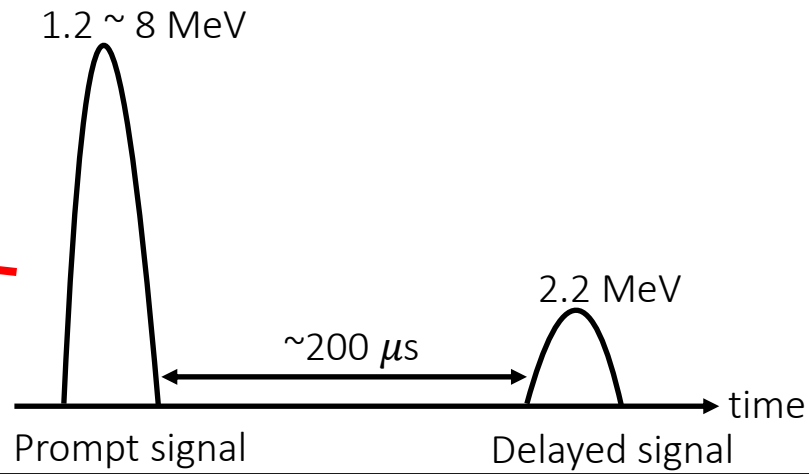
Detection Channels

Inverse beta decay (IBD)

- Two detection channels: n-Gd vs. n-H



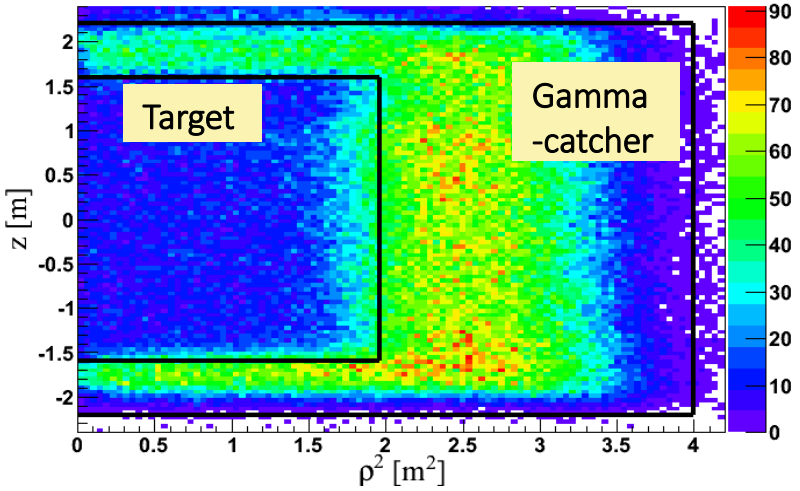




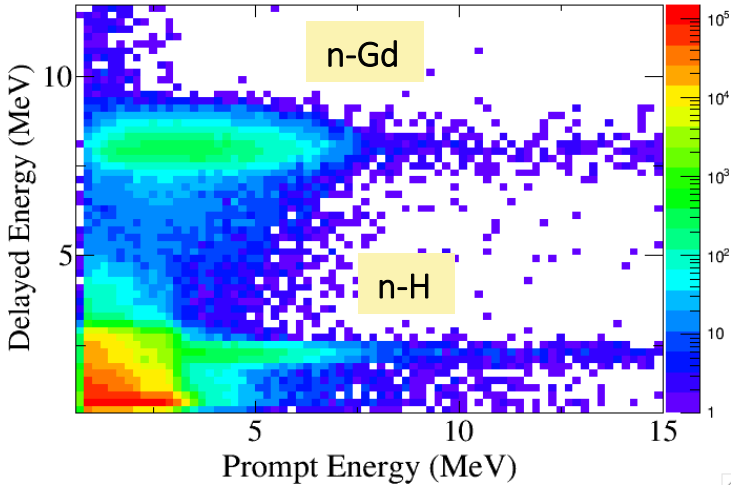
n-H Channel

Neutron capture on H (n-H channel)

- Characteristics
  - Mainly in the gamma-catcher region
  - Larger interaction volume
    - ~ 2.3 X more IBD events expected



- 2.223 MeV single gamma-ray
  - More exposed to low E radioactive background



➢ An independent measurement of θ_{13}

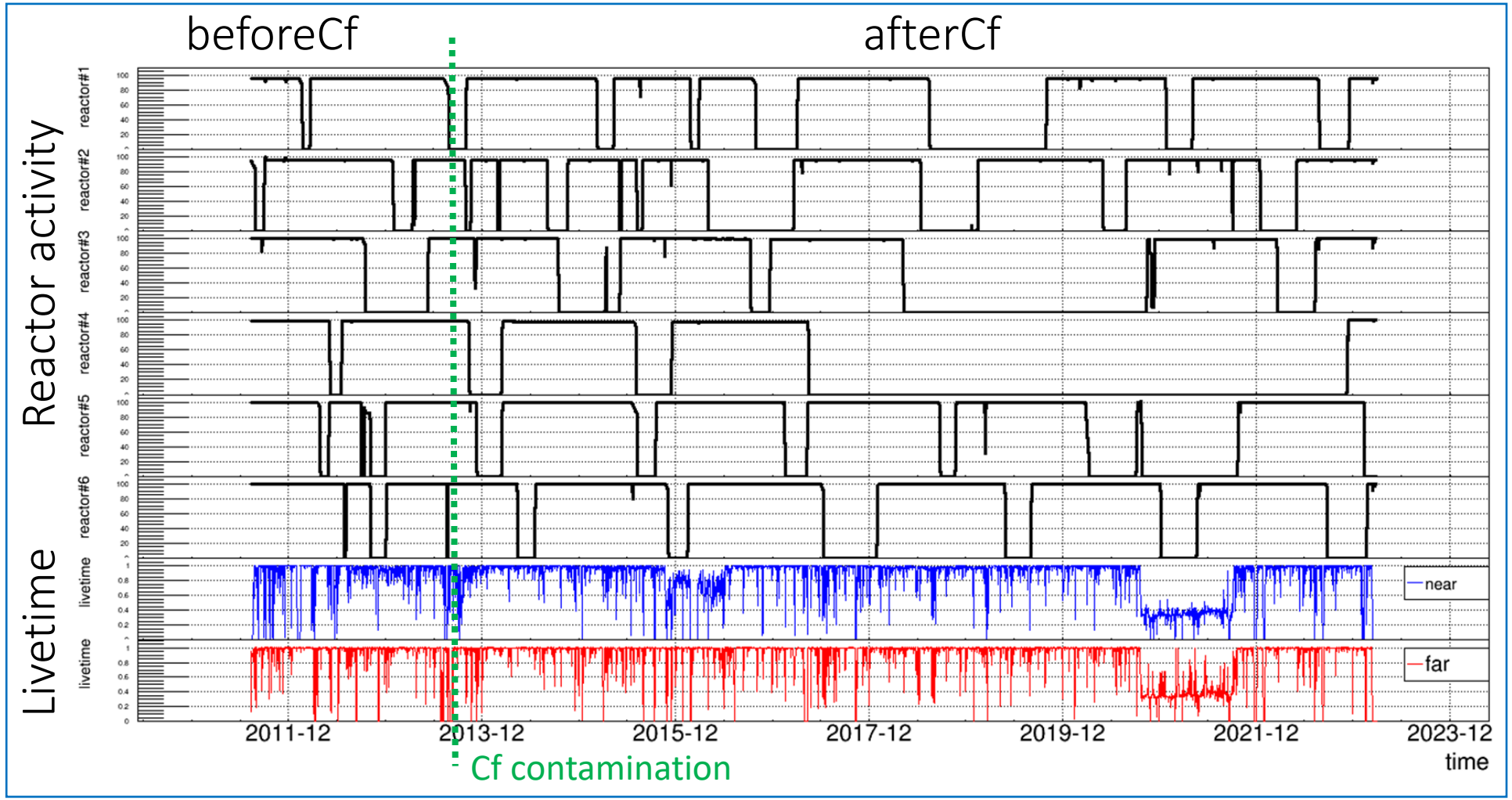
✓ A consistency check with the n-Gd result

✓ Reduction in uncertainties through the combined n-Gd and n-H analysis

Data Set

Data taking period

- Aug. 2011 - Mar. 2023: corresponding to ~ 3,800 livedays



Major Results from RENO & Status

- Precise measurement of $|\Delta m^2_{ee}|$ and θ_{13} with n-Gd capture
  - Phys. Rev. Lett. 108, 191802 (2012) - 229[d]
  - Phys. Rev. Lett. 116, 211801 (2016) - 500[d]
  - Phys. Rev. D 98, 012002(2018) - 500[d]
  - Phys. Rev. Lett. 121, 201801 (2018) - 2200[d]
  - Phys. Rev. D 111, 112006 (2025) - 3800[d]
- Measurement of θ_{13} with n-H capture
  - JHEP 04 029 (2020) - 1500[d]
  - 3800 days of data
- Reactor neutrino yield and spectrum
  - Phys. Rev. Lett. 122, 232501 (2019) - 1800[d]
  - Phys. Rev. D 104, L111301 (2021) - 2900[d]
  - 3800 days of data
- sterile neutrino search
  - Phys. Rev. Lett. 125, 191801 (2020) - 2200[d]
  - Phys. Rev. D 105, L111101 (2022) - 2509[d] RENO + 180[d] NEOS
  - 3800 days of data

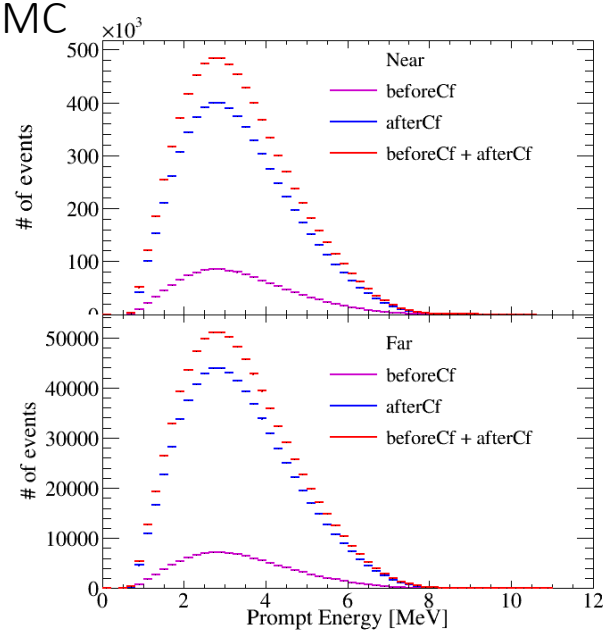
Analyses with the full 3800-day data set

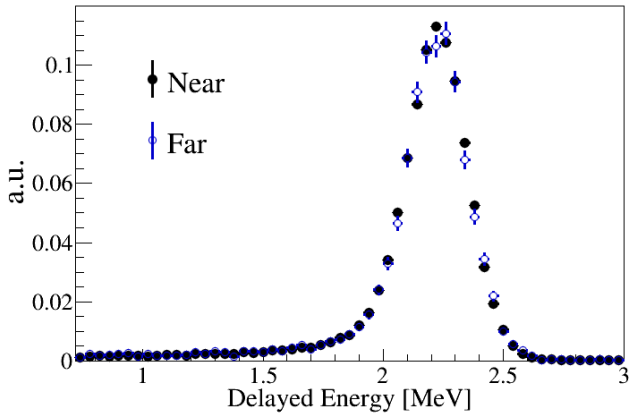
n-H Oscillation Analysis – Event Selection

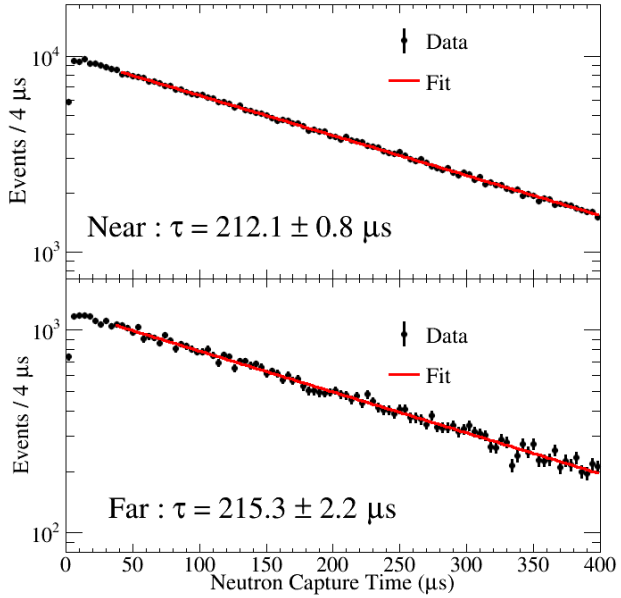
IBD coincidence selection

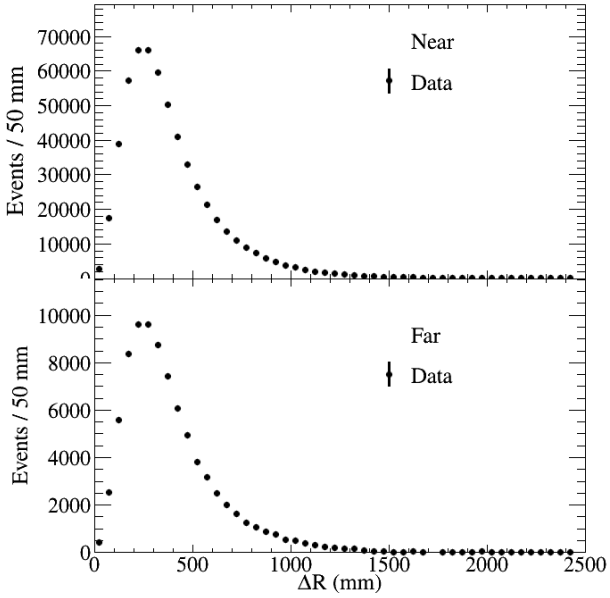
- Prompt energy requirement $1.2 < \mathrm{E_p} < 8\ \mathrm{MeV}$
- Delayed energy requirement $\mathrm{E_d} = 2.223 \pm 2\sigma\ \mathrm{MeV}$
- Prompt–delayed temporal coincidence $2 < \Delta T < 400\ \mu s$
- Prompt–delayed spatial coincidence $\Delta R < 450\ \mathrm{mm}$

MC









n-H Oscillation Analysis – Event Selection

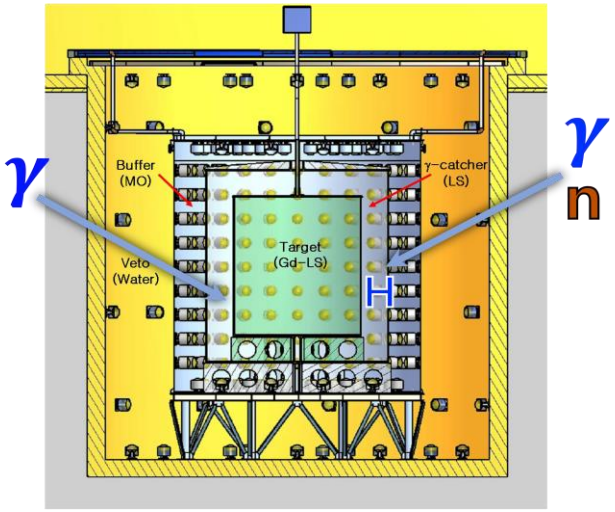
Background suppression strategy

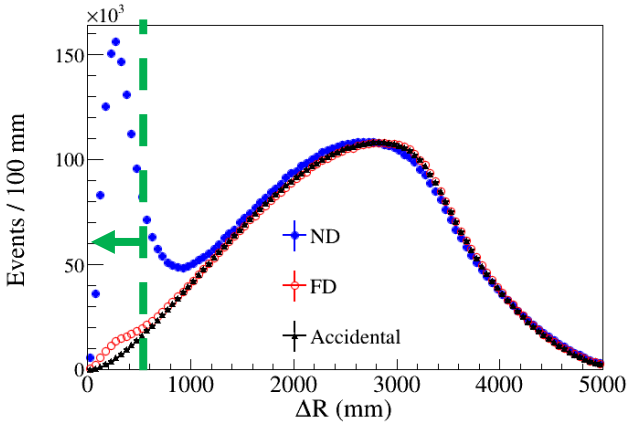
- Muon veto
  - Time correlation with preceding muons
    - Apply energy-dependent vetoes
- Ambient γ cut
  - External radioactivity rejection
    - Require $Q_{max}/Q_{tot} < 0.07\ (\text{prompt}),\ 0.06\ (\text{delayed})$
- Neutron multiplicity cut
  - Additional triggers from multiple neutrons
    - Reject IBD candidates with additional triggers around the prompt signal
- ^{252}Cf cut
  - Correlated events and spatially localized clusters
    - Reject IBD candidates associated with Cf-like events or the contamination region

n-H Oscillation Analysis – Backgrounds

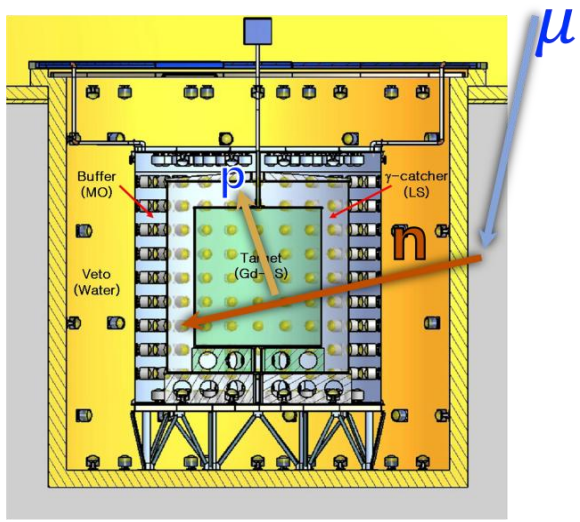
Backgrounds remain after the suppression cuts

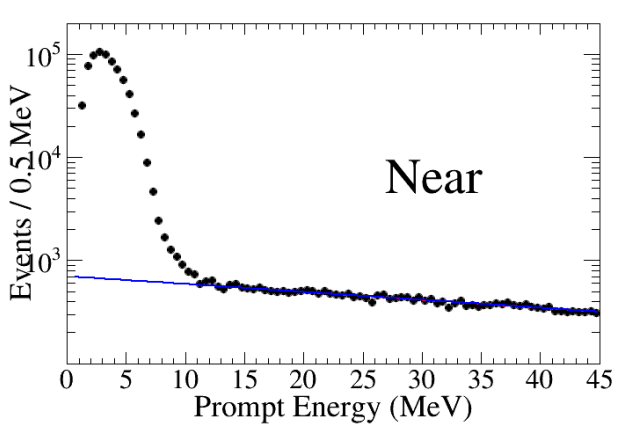
Accidental background



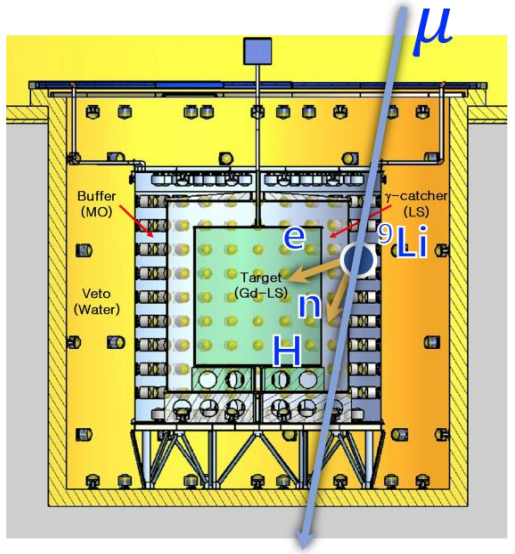


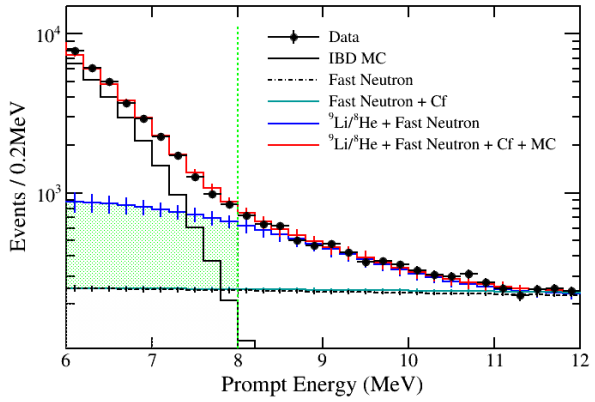
Fast neutron background



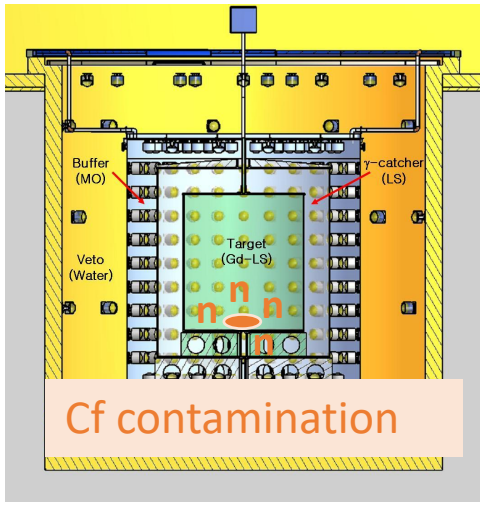


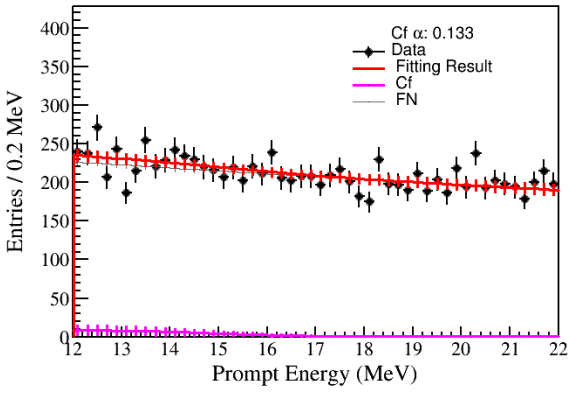
Li/He background





Cf background



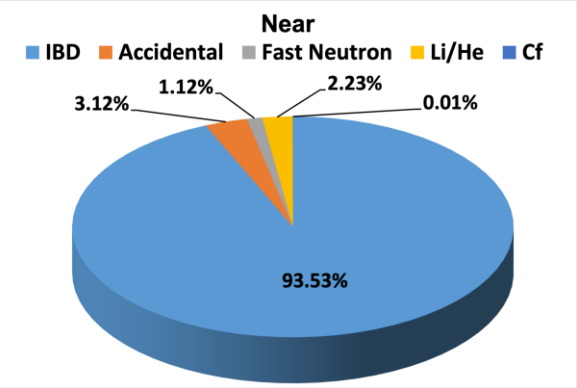


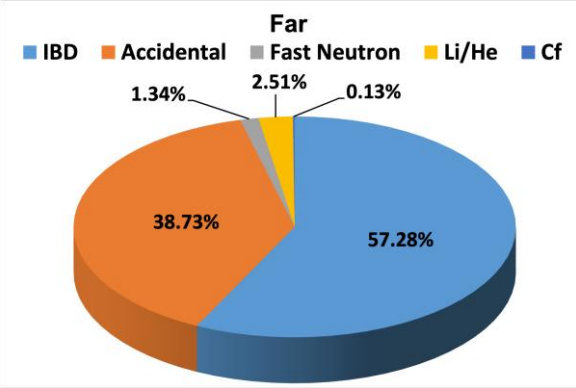
n-H Oscillation Analysis – Results

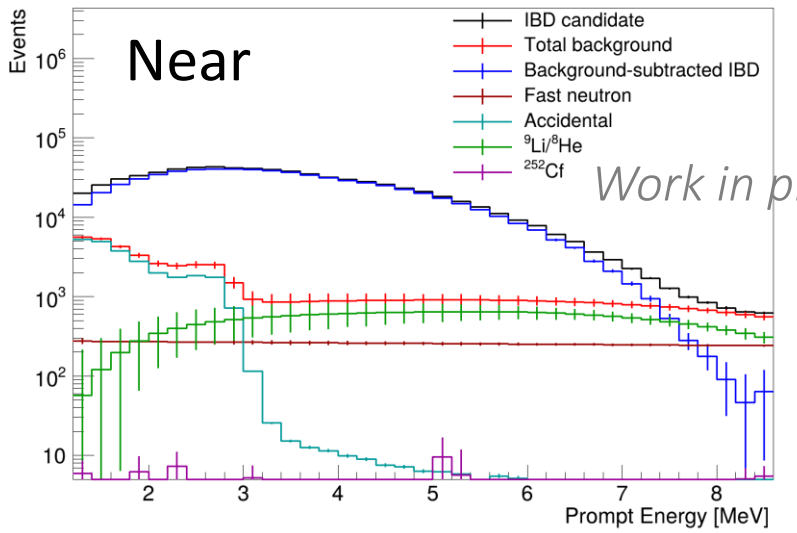
IBD event and background summary

	ND	FD
IBD candidates	904,607	196,166
	(1,211,995)	(144,667)
Accidental background (/day)	8.524 ± 0.004	20.327 ± 0.006
Fast neutron (/day)	3.062 ± 0.067	0.705 ± 0.032
^{9}Li/^{8}He (/day)	6.095 ± 0.495	1.315 ± 0.155
^{252}Cf (/day)	0.027 ± 0.014	0.069 ± 0.018
Total background (/day)	17.708 ± 0.500	22.416 ± 0.159
IBD signal (/day)	255.840 ± 0.576	30.062 ± 0.200
	(357.39 ± 0.38)	(36.64 ± 0.16)

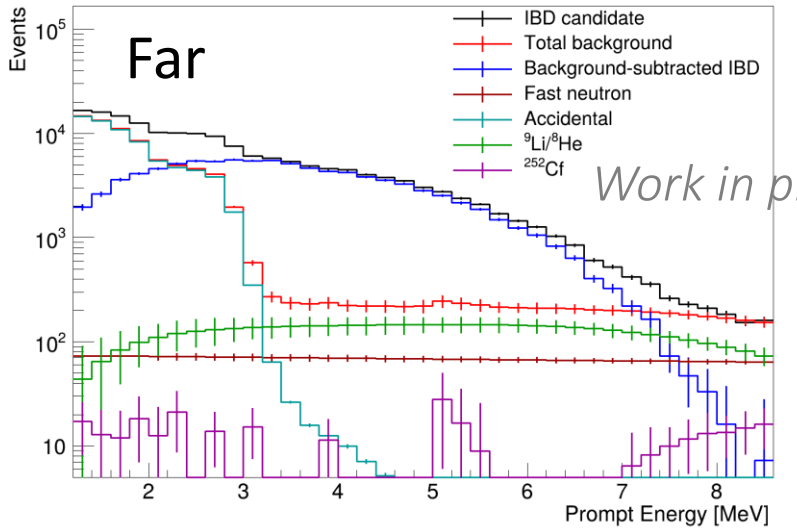
* Values in parentheses: n-Gd; otherwise: n-H.







Work in progress



Work in progress

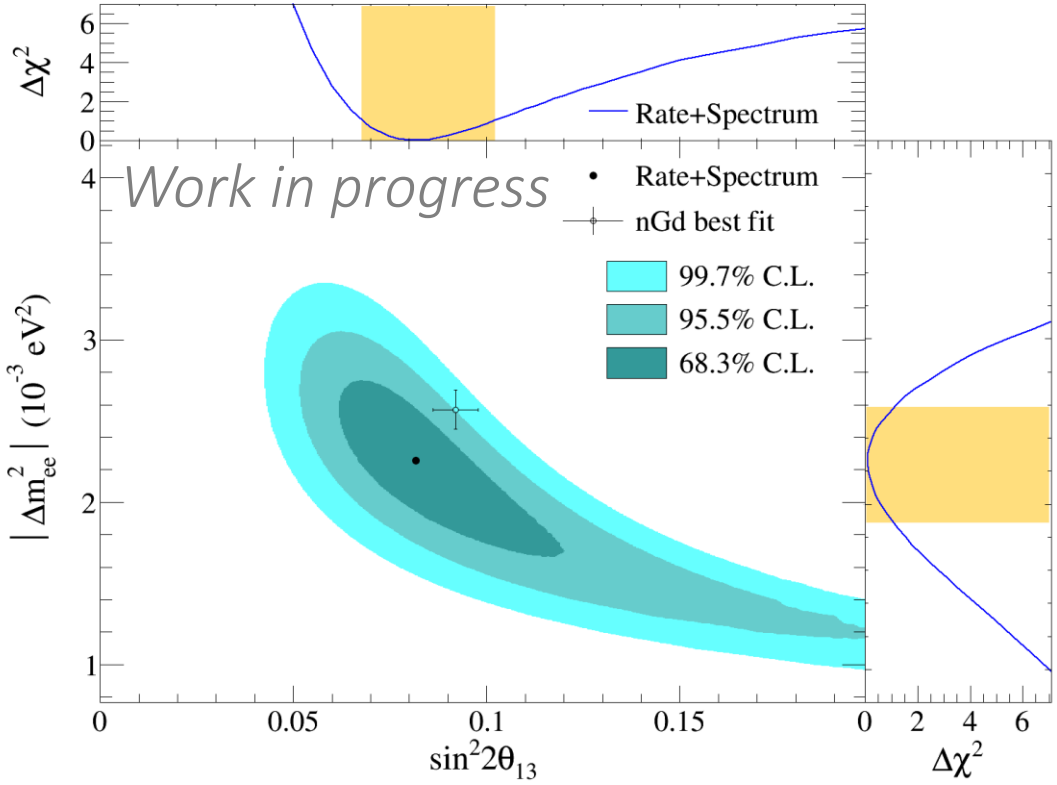
n-H Oscillation Analysis – Results

First n-H only rate and spectral analysis in RENO *Work in progress*

$$\sin^2 2\theta_{13} = 0.0817\ ^{+0.0134}_{-0.0095}(\text{stat.})\ ^{+0.0155}_{-0.0102}(\text{syst.})$$

$$|\Delta m^2_{ee}| = 2.26\ ^{+0.25}_{-0.28}(\text{stat.})\ ^{+0.21}_{-0.24}(\text{syst.}) \times 10^{-3}\text{eV}^2$$

- Consistent with the n-Gd result within the uncertainties



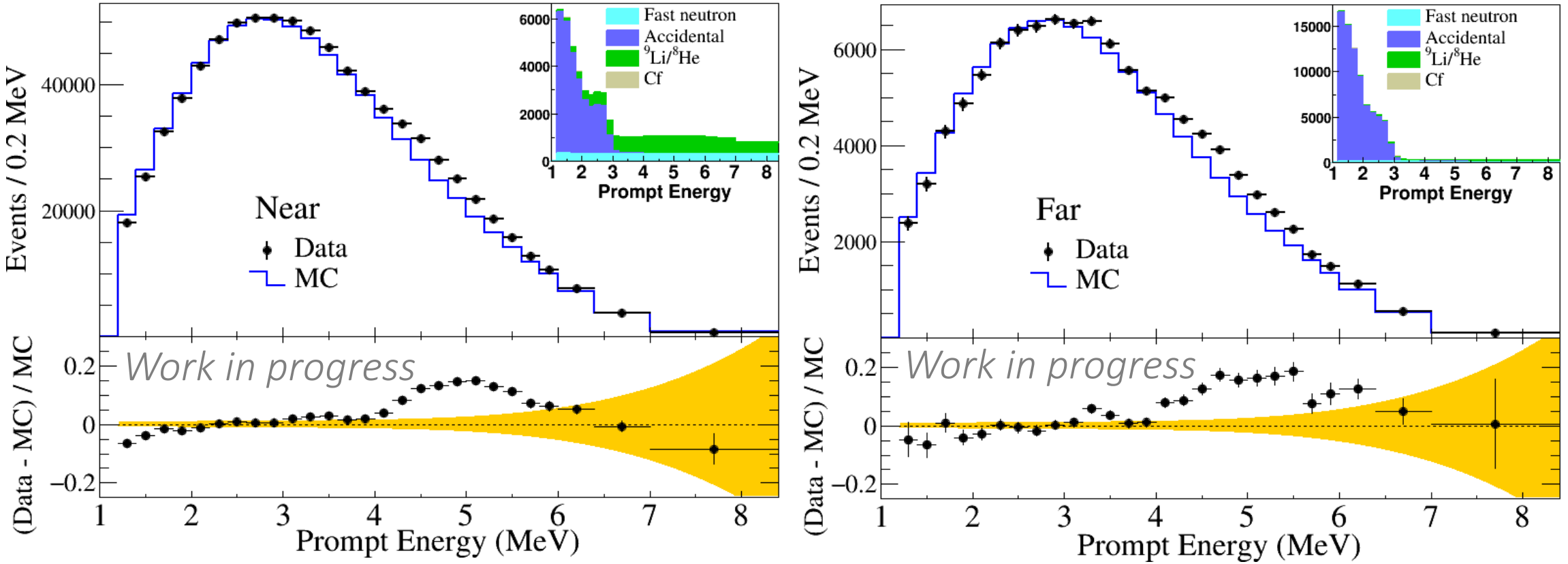
- Systematic contributions

Source	$\sin^2 2\theta_{13}$	$\lvert\Delta m^2_{ee}\rvert$ $(10^{-3}\,\text{eV}^2)$
Reactor	···	···
Efficiency	+0.0036, −0.0051	+0.04, −0.09
Background	+0.0045, −0.0041	+0.08, −0.12
Signal loss	+0.0003, −0.0016	···, −0.03
Energy scale	+0.0096, −0.0032	+0.17, −0.20

n-H Oscillation Analysis – Results

- An excess of approximately 3% of the total IBD events is observed around 5 MeV in both detectors compared to the Huber-Mueller model.

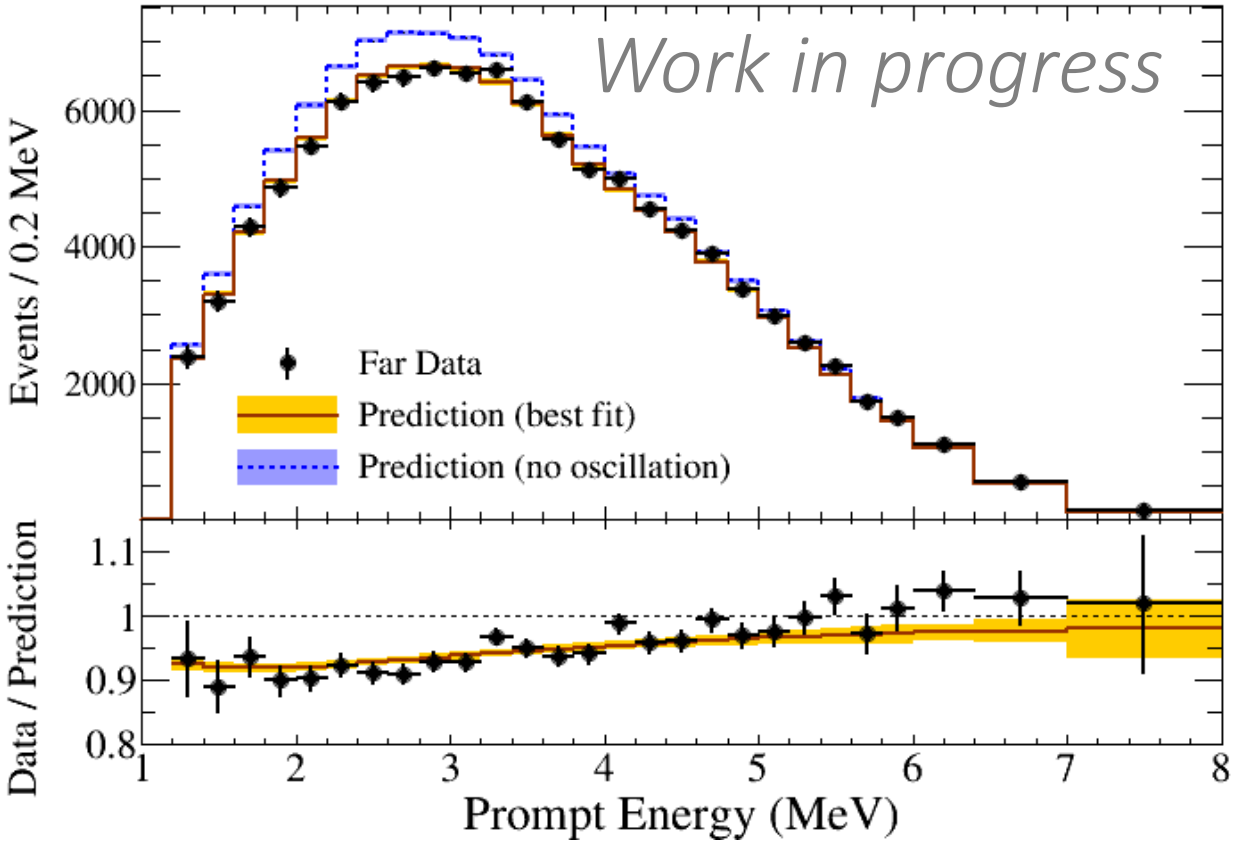
@ best fit of the n-H only analysis

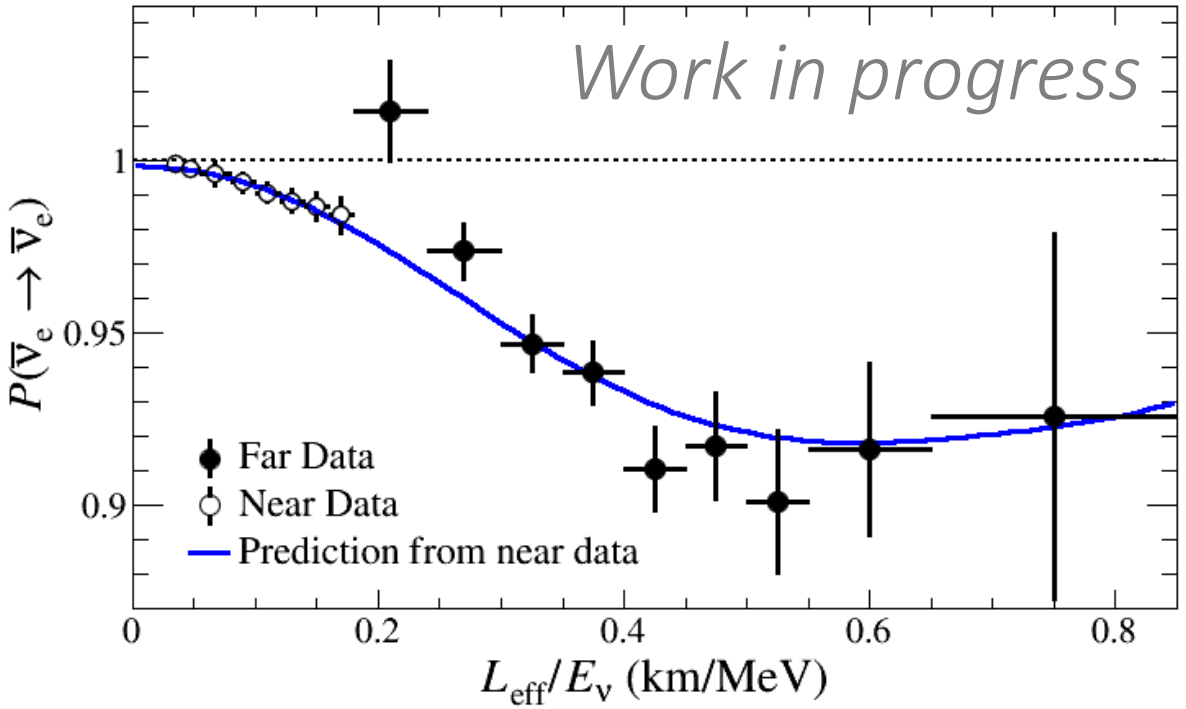


n-H Oscillation Analysis – Results

- The observed deficit and spectral distortion are well described by the best-fit oscillation prediction.

@ best fit of the n-H only analysis





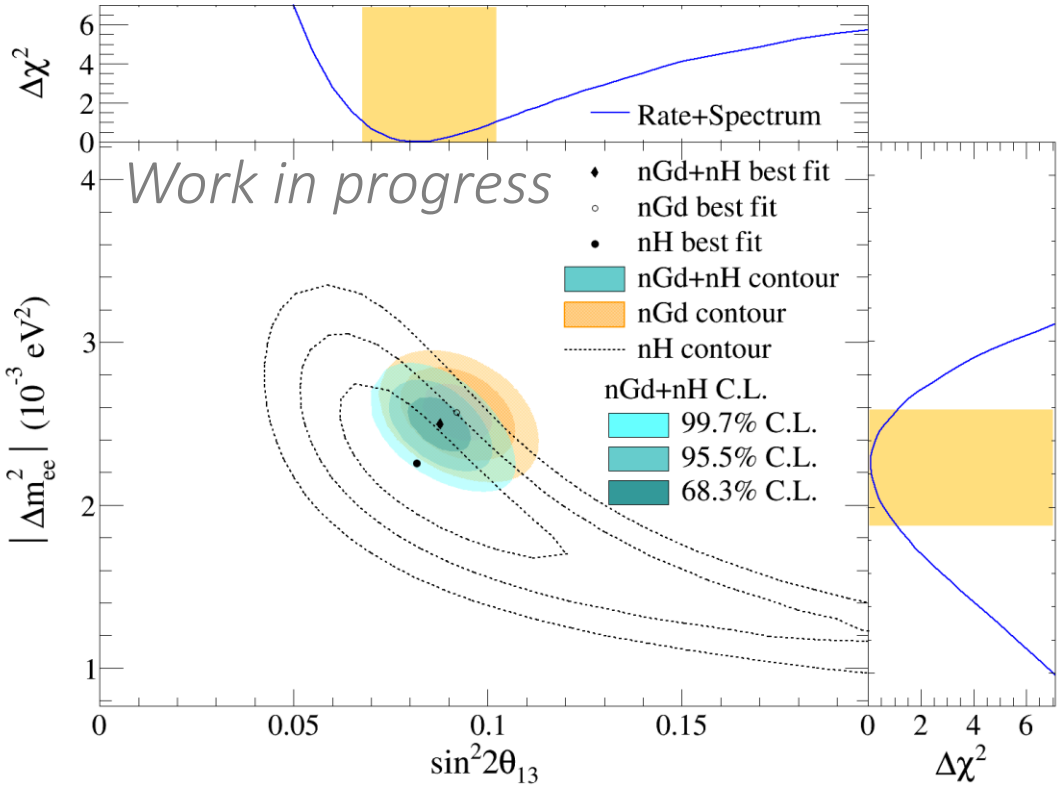
n-H Oscillation Analysis – Results

First combined n-Gd + n-H rate and spectral analysis in RENO *Work in progress*

$$\sin^2 2\theta_{13} = 0.0874\ ^{+0.0038}_{-0.0037}(\text{stat.})\ ^{+0.0038}_{-0.0036}(\text{syst.})$$ ~10% uncertainty reduction

$$|\Delta m^2_{ee}| = 2.50\ ^{+0.09}_{-0.10}(\text{stat.})\ ^{+0.06}_{-0.06}(\text{syst.}) \times 10^{-3}\text{eV}^2$$ ~3% uncertainty reduction

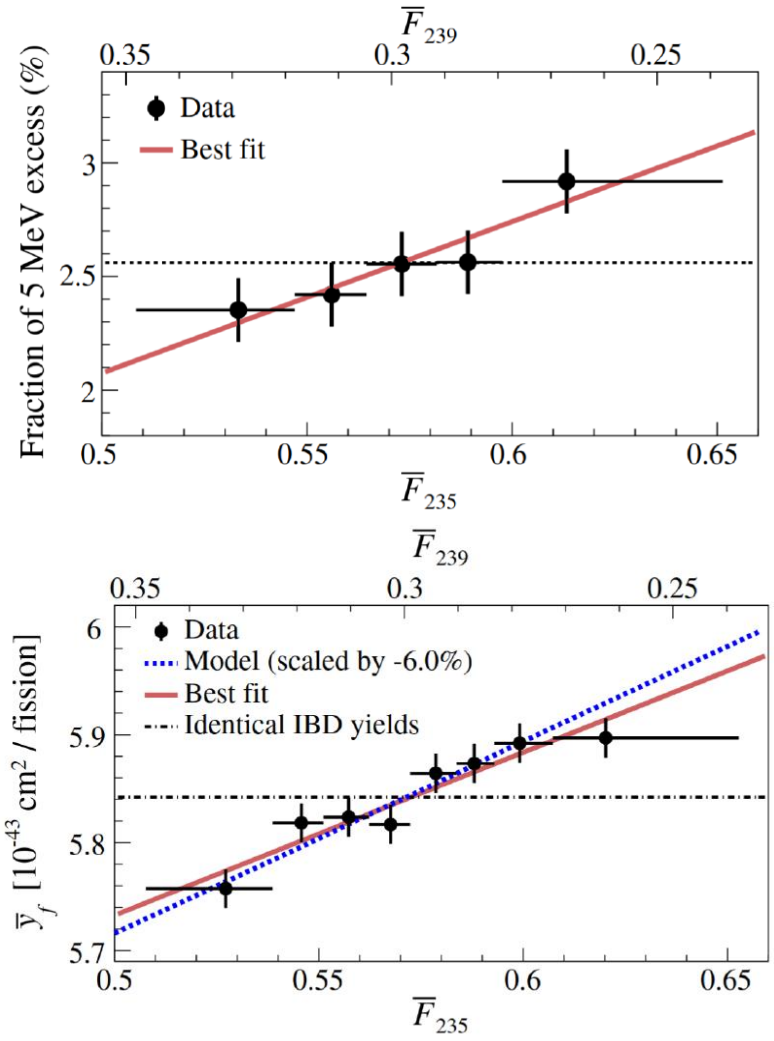
- Consistent with the individual n-Gd and n-H results



- Systematic contributions

Source	$\sin^2 2\theta_{13}$	$\lvert\Delta m^2_{ee}\rvert$ $(10^{-3}\,\text{eV}^2)$
Reactor	...	...
Efficiency	+0.0019, −0.0020	+0.01, −0.01
Background	+0.0013, −0.0013	+0.02, −0.03
Signal loss	+0.0008, −0.0009	...
Energy scale	+0.0016, −0.0014	+0.05, −0.06

Fuel Decomposition - Motivation



- Fuel dependence:
  - Four main fission isotopes: ^{235}U, ^{238}U, ^{239}Pu and ^{241}Pu
  - **Fuel evolution provides a natural handle to separate the ^{235}U and ^{239}Pu contributions.**

- Analysis goal:
  - Two anomalies in SBL experiments → Flux deficit, 5MeV excess
  - To Probe the origin of these two anomalies

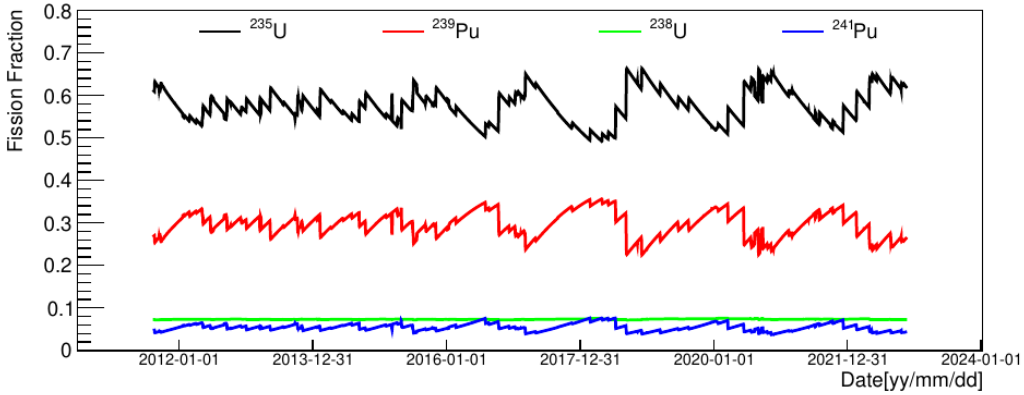
  1. Decompose ^{235}U and ^{239}Pu spectra
  2. Identify the isotopic origin

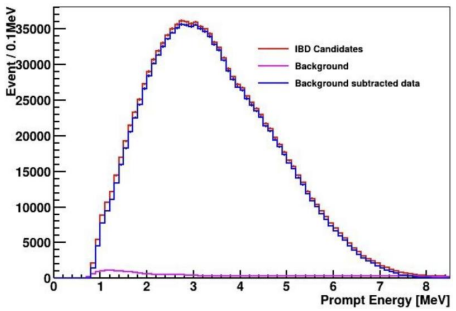
The distinct fuel evolution of ^{235}U and ^{239}Pu provides the lever arm for the decomposition. (RENO PRL. 2019)

Fuel Decomposition - Analysis

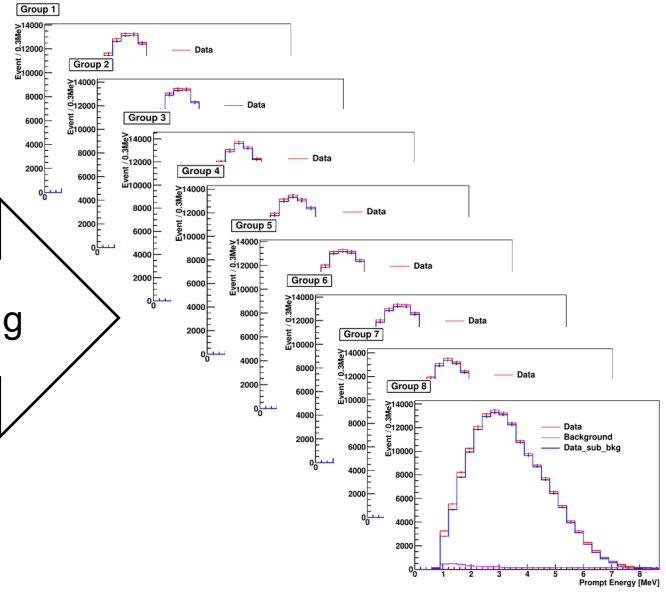
- The near-detector IBD sample is divided into eight groups according to the effective fission fractions.
- Eight fuel-composition groups convert the time-dependent fission fractions into a simultaneous spectral fit for ^{235}U and ^{239}Pu.
  - $\chi^2(\mathrm{Y}^{\mathrm{obs}};\mathrm{Y}^{235},\mathrm{Y}^{239}) = \sum_{\mathrm{g}}\sum_{\mathrm{i}}\left(\frac{\mathrm{Y}^{\mathrm{obs}}_{\mathrm{g,i}}-\mathrm{Y}^{\mathrm{exp}}_{\mathrm{g,i}}}{\sigma^{\mathrm{obs}}_{\mathrm{g,i}}}\right)^2 + \text{pull terms}$
  - g : group index
  - i : energy bin index

Fuel cycle of the Hanbit reactors



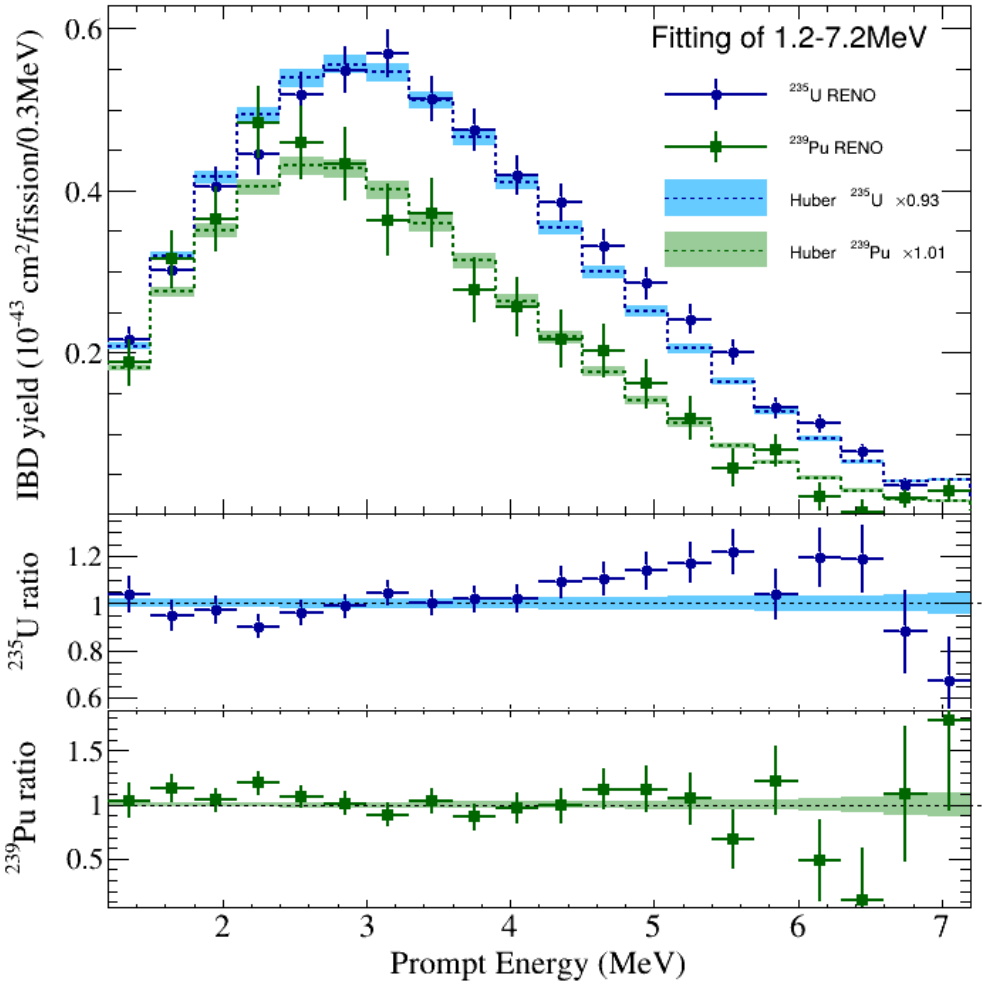


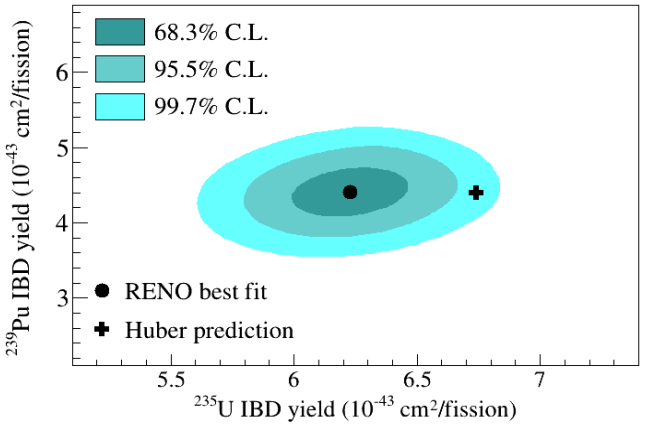
grouping

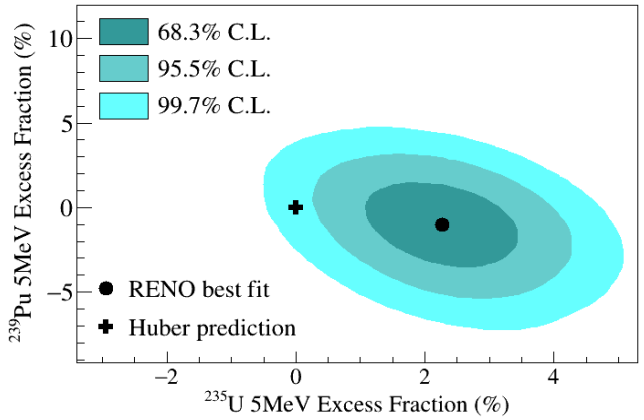


IBD spectrum in the near detector

Fuel Decomposition - Results







The fuel-dependent fit points to ^{235}U as the main source of the observed yield deficit.

- ^{235}U: 6.24 ± 0.07 (stat.) ± 0.14 (syst.)

  More than 2σ below the Huber–Mueller prediction

- ^{239}Pu: 4.43 ± 0.14 (stat.) ± 0.17 (syst.)

  Consistent with the prediction within the present uncertainty

Fuel Decomposition - Plan

- Fuel decomposition using the nH sample
- Combined nGd+nH analysis

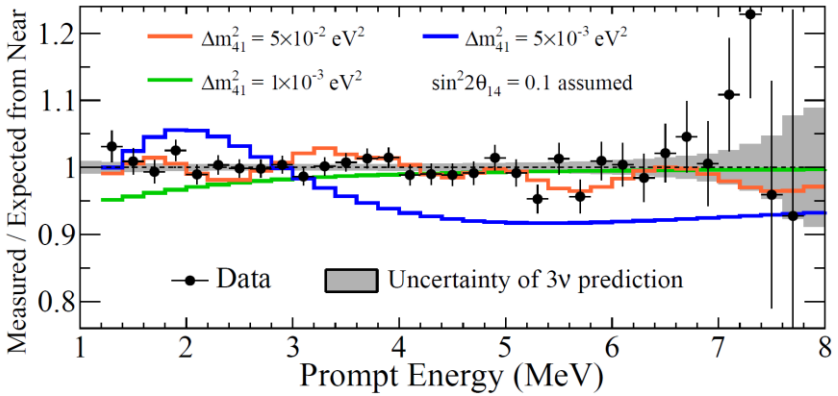
The nH sample provides an **independent cross-check** and improves the **precision of the isotope spectra** in the combined analysis.

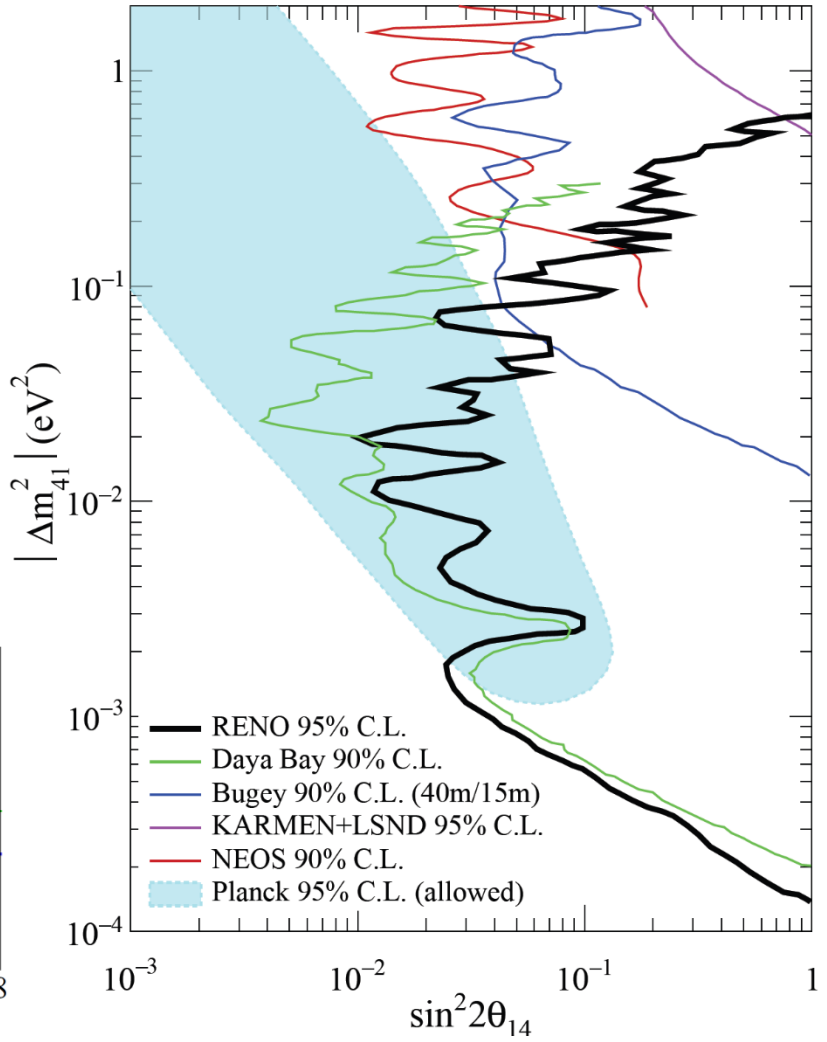
- Paper submission is planned for this year.

Light Sterile Neutrino Search - Motivation

- In 2020, RENO published a search for light sterile neutrino using 2200 live days.
  - Phys. Rev. Lett. 125, 191801 (2020)

- In this analysis,
  - Exposure: 2200 → 3800 live days
  - Wilks-based contour method → CLs method





Phys. Rev. Lett. 125, 191801 (2020)

Light Sterile Neutrino Search - CLs Method

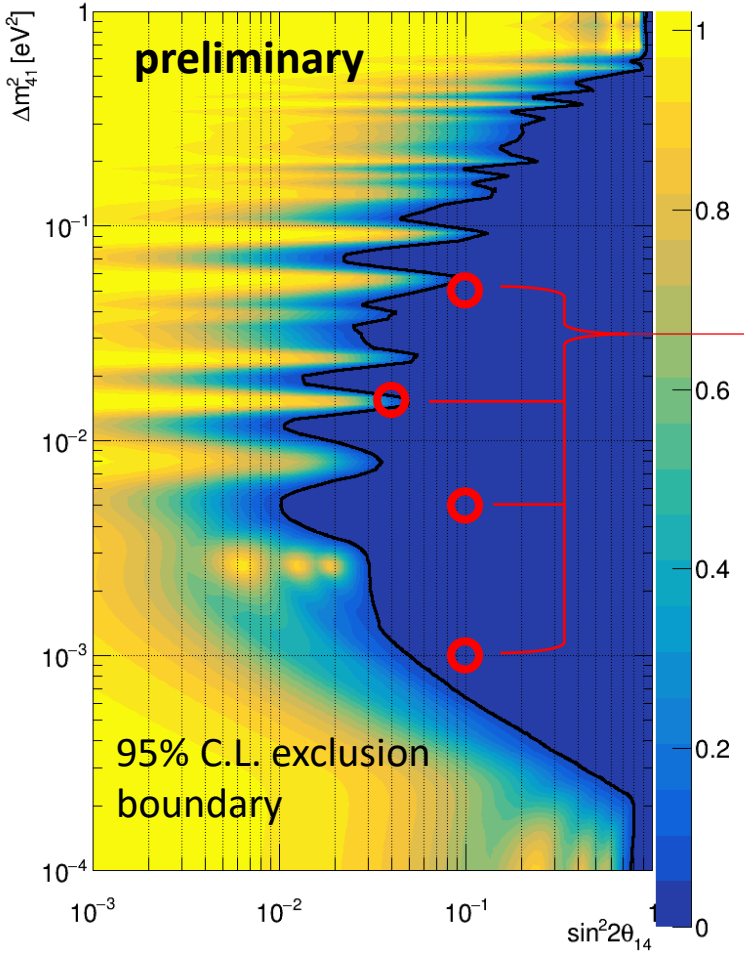
- Traditional Method based on Wilks' Theorem
  - $\Delta\chi^2(\eta) = \chi^2(\eta) - \chi^2_{\min}$ $\quad\quad$ $\eta = (\sin^2 2\theta_{14}, \Delta m^2_{41})$
  - Exclude η if $\Delta\chi^2(\eta) > 5.99$ (95%, 2 d.o.f.)

- CLs method
  - $\Delta T_{obs}(\eta) = \chi^2_{4\nu}(\eta) - \chi^2_{3\nu}$
  - $p_{4\nu} = P(\Delta T \geq \Delta T_{obs}|H_{4\nu})$, $p_{3\nu} = P(\Delta T \geq \Delta T_{obs}|H_{3\nu})$
  - $CLs(\eta) = \frac{p_{4\nu}}{p_{3\nu}} = 0.05$ (95%)
  - The ΔT distribution is evaluated with the Gaussian approximation

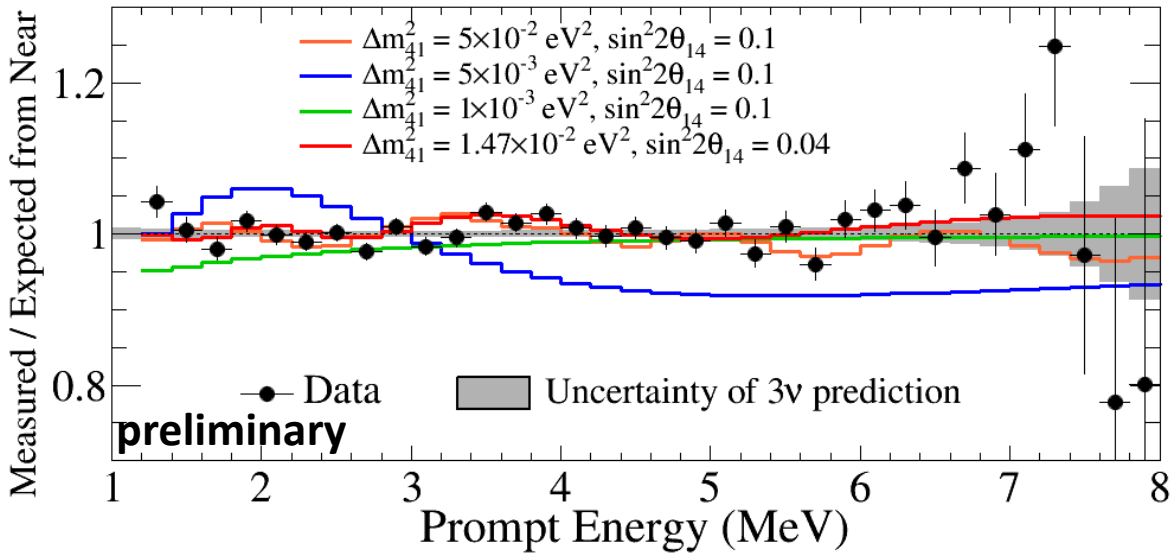
Why CLs?
The denominator suppresses exclusions in regions where the 3ν and 4ν spectra are difficult to distinguish. Thus, CLs avoids excluding sterile parameters when the experiment has limited sensitivity.
Gaussian CLs approximation: X. Qian et al., NIM A 827 (2016) 63–75.

Light Sterile Neutrino Search - Results (Preliminary)

$\mathrm{CLs}(\eta)$



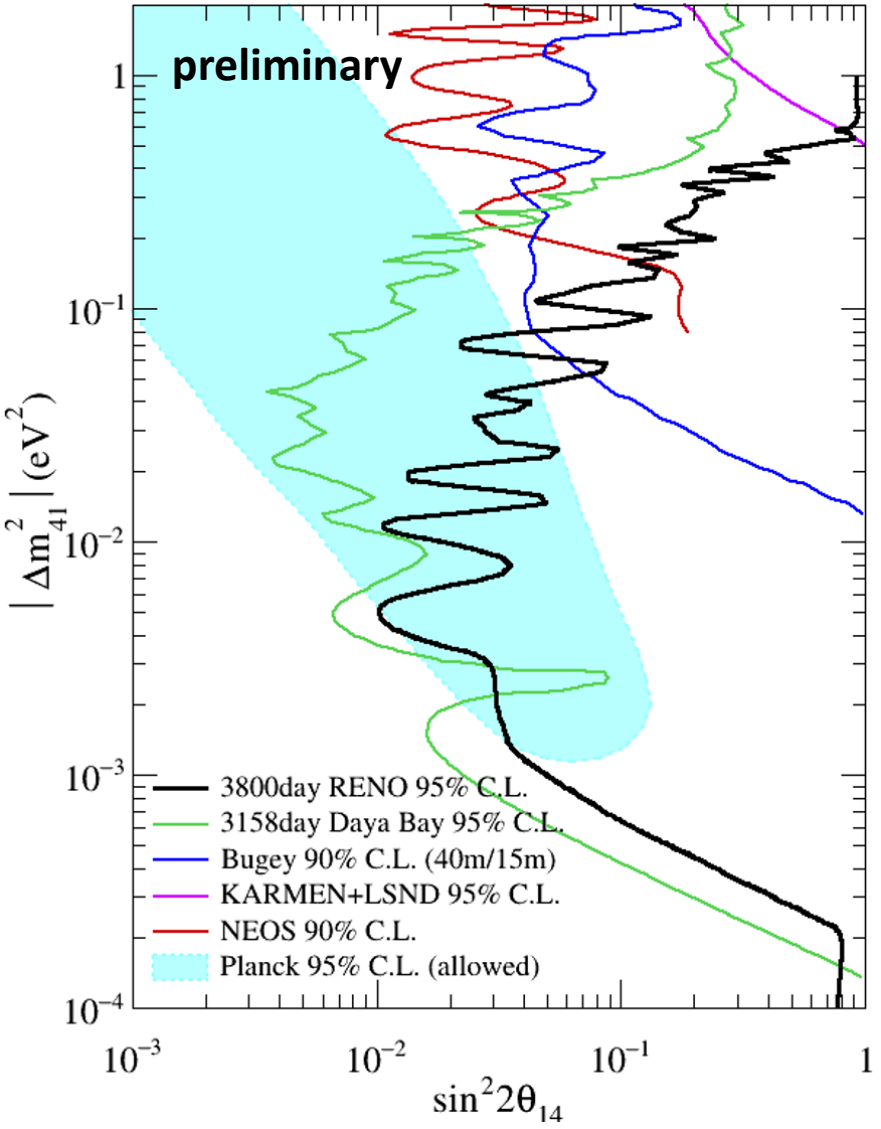
Ratio between measured and expected spectra



- The measured far-to-near spectrum ratio is consistent with the three-neutrino prediction.
- The CLs exclusion reflects only regions where the 3ν and 4ν hypotheses are experimentally distinguishable.
- Generate pseudo-experiments under the 3ν hypothesis to derive the median expected contour and $\pm1\sigma$ sensitivity band.

Light Sterile Neutrino Search
- Comparison with Other Experiments (Preliminary)

- The 3800-day RENO result provides an updated CLs exclusion limit with the full data set.
- RENO provides an independent constraint in the low-Δm^2_{41} region through its near–far spectral comparison.
- The RENO and Daya Bay contours use the same 95% C.L. CLs prescription, enabling a statistically consistent comparison.



Summary

- The final 3800-day RENO data set supports multiple precision reactor-neutrino measurements.

- n-H Oscillation measurement:
  - Simultaneous determination of $sin^2\,2\theta_{13}$ and $|\Delta m^2_{ee}|$ using the 3800-day n-H sample
  - The n-Gd + n-H joint analysis with the 3800-day dataset

Work in progress

$$\sin^2 2\theta_{13} = 0.0874\ ^{+0.0038}_{-0.0037}(\text{stat.})\ ^{+0.0038}_{-0.0036}(\text{syst.})$$

$$|\Delta m^2_{ee}| = 2.50\ ^{+0.09}_{-0.10}(\text{stat.})\ ^{+0.06}_{-0.06}(\text{syst.})\ \times\ 10^{-3}\text{eV}^2$$

- Fuel decomposition:
  - The fuel-dependent fit indicates that the ^{235}U component is the primary source of the observed yield deficit.
  - An nH cross-check and a combined nGd+nH analysis are in progress.

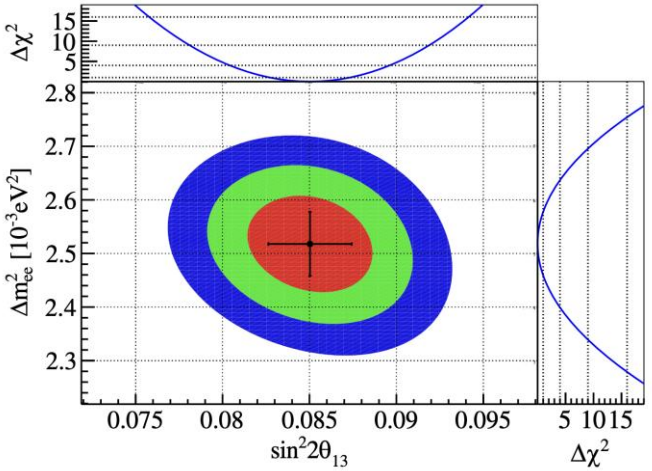
- Light sterile-neutrino search:
  - The 3800-day analysis uses a CLs construction that accounts for limited experimental sensitivity.
  - Expected-contour studies are in progress.

Backup

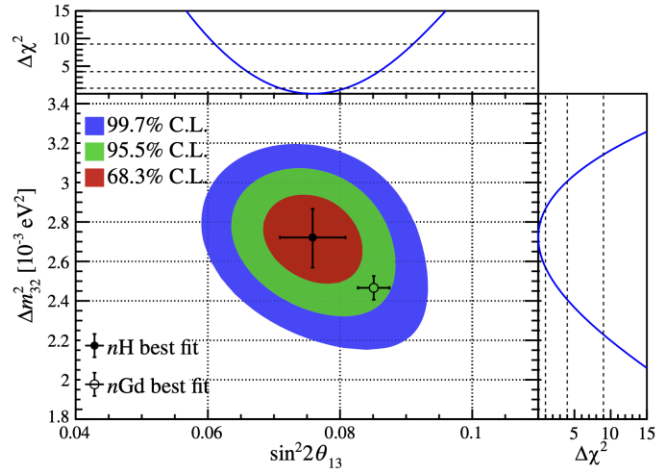
Daya-Bay

Daya-Bay experiment result

- n-Gd: PRL 130, 161802 (2023)
  - Livetime [d] — 3158
  - IBD candidate — 5.55×10^6
  - $\sin^2 2\theta_{13}$ — 0.0851 ± 0.0024
  - Δm^2_{32} $[10^{-3}\ \mathrm{eV}^2]$ — 2.466 ± 0.060



- n-H: PRL 133, 151801 (2024)
  - Livetime [d] — 1958
  - IBD candidate — 3.60×10^6
  - $\sin^2 2\theta_{13}$ — $0.0759^{+0.0050}_{-0.0049}$
  - Δm^2_{32} $[10^{-3}\ \mathrm{eV}^2]$ — $2.72^{+0.14}_{-0.15}$



> n-Gd + n-H error-weighted mean

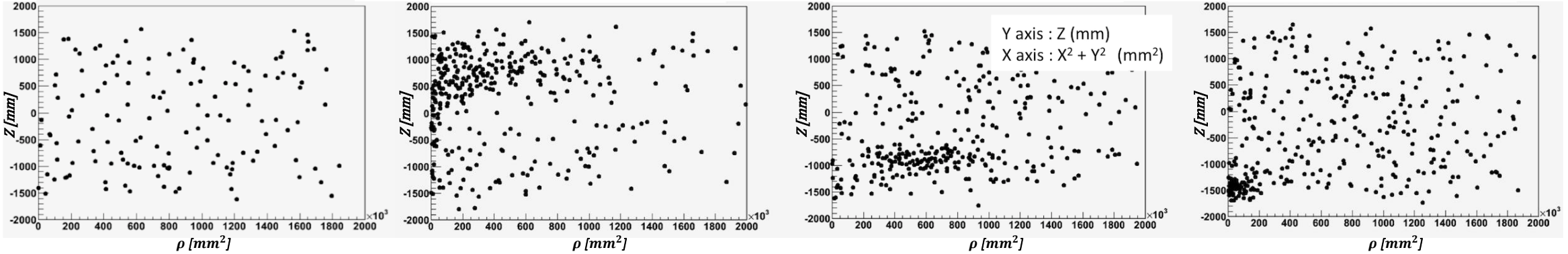
- $\sin^2 2\theta_{13}$ — 0.0833±0.002
- Δm^2_{32} $[10^{-3}\ \mathrm{eV}^2]$ — –

Dataset

Data taking issue

- ^{252}Cf contamination during a calibration campaign
  - Oct. 27th , 2012 (near) / Sep. 28th , 2012 (far)

26th Oct. 2012 | 27th Oct. 2012: Cf contamination | 30th Oct. 2012 | 7th Nov. 2012



  - Data samples are divided into “beforeCf” and “afterCf” periods.

  - Spontaneous fission of ^{252}Cf produces multiple neutrons.
    - ~3.76 neutrons per fission
    - Cf rejection cut is applied to the afterCf period during event selection.
    - Residual Cf events are estimated and subtracted as a background.

Event Selection

Background suppression

Category	Selection criterion	Near		Far	
		beforeCf	afterCf	beforeCf	afterCf
Muon veto	Li/He veto (a)	700 ms ($E_\mu > 1.6$ GeV)		700 ms ($E_\mu > 1.5$ GeV)	
	Li/He veto (b)	400 ms ($1.5 < E_\mu < 1.6$ GeV)		500 ms ($1.2 < E_\mu < 1.5$ GeV)	
	Li/He veto (c)	200 ms ($1.4 < E_\mu < 1.5$ GeV)		200 ms ($1.0 < E_\mu < 1.2$ GeV)	
	Muon veto	1 ms ($0.07 < E_\mu < 1.4$ GeV)		1 ms ($0.07 < E_\mu < 1.0$ GeV)	
	Sub-muon veto	1 ms ($0.02 < E_\mu < 0.07$ GeV, $N_{\text{veto}}^{\text{hit}} > 50$)			
Ambient γ cut	$Q_{\max}/Q_{\text{tot}}$ (prompt)			< 0.07	
	$Q_{\max}/Q_{\text{tot}}$ (delayed)			< 0.06	
Neutron multiplicity cut	Any trigger preceding S1	300 μs	500 μs	300 μs	500 μs
	ID or ID&OD trigger preceding S1	300–600 μs	500–600 μs	300–600 μs	500–600 μs
	ID trigger following S1			800 μs	
	ID&OD trigger following S1	100 μs	200 μs	100 μs	200 μs
^{252}Cf cut	Cf-like single event after S1	–	–	–	$E > 3$ MeV $Q_{\max}/Q_{\text{tot}} < 0.04$ $\Delta T < 30$ s, $\Delta R < 50$ cm $R_{xy} < 30$ cm
	Cf hotspot region	–	–	–	around (12.5, 12.5) cm $-170 < z < 120$ cm

Detection Efficiency and Signal Loss

Detection efficiency

- Evaluated using data and MC

	Detection efficiency (%)	Uncorrelated uncertainty (%)
Target protons	···	···
IBD cross-section	···	···
Additional fraction	100.22	···
Trigger efficiency	78.79	0.02
H capture fraction	61.10	0.03
Prompt energy	97.83	0.08
Delayed energy	87.80	0.11
Time coincidence	85.09	0.04
Spatial coincidence	70.22	0.09
S1 Q_{max}/Q_{tot}	97.31	0.07
S2 Q_{max}/Q_{tot}		
Before ^{252}Cf (ND)	92.20	0.18
Before ^{252}Cf (FD)	91.34	0.23
After ^{252}Cf (ND)	90.88	0.20
After ^{252}Cf (FD)	90.35	0.22
Total detection efficiency		
Before ^{252}Cf (ND)	22.21	0.07
Before ^{252}Cf (FD)	22.01	0.07
After ^{252}Cf (ND)	21.90	0.07
After ^{252}Cf (FD)	21.77	0.07

Muon-induced

IBD coincidence

Signal loss

- Evaluated using data

	Signal loss [%]	
Selection criterion	**ND**	**FD**
Muon veto	21.638 ± 0.001	11.794 ± 0.001
Neutron multiplicity cut	26.493 ± 0.020	15.824 ± 0.025
^{252}Cf cut	–	1.275 ± 0.070
Flasher cut	2.074 ± 0.019	4.006 ± 0.069
Total signal loss	$\mathbf{43.585 \pm 0.019}$	$\mathbf{29.583 \pm 0.073}$

For individual cuts

	Signal loss (%)	
	ND	**FD**
Flasher removal (iii)	2.074 ± 0.019	4.006 ± 0.069
Muon veto (iv)	21.638 ± 0.001	11.794 ± 0.001
Preceding-trigger veto (ix-a)	19.494 (< 0.001)	7.216 (< 0.001)
Preceding-ID veto (ix-b)	1.941 (< 0.001)	1.342 (< 0.001)
Subsequent-ID veto (ix-c)	4.574 (< 0.001)	7.851 (< 0.001)
Subsequent-ID–OD veto (ix-d)	2.423 ± 0.027	0.209 ± 0.029
^{252}Cf removal (x-a)	–	1.039 ± 0.063
^{252}Cf hotspot removal (x-b)	–	0.238 ± 0.030
Total signal loss	43.585 ± 0.019	29.583 ± 0.073

Backgrounds

Cosmogenic background production

- Fast neutron background
- Li/He background (Phys. Rev. D 106, 012005)

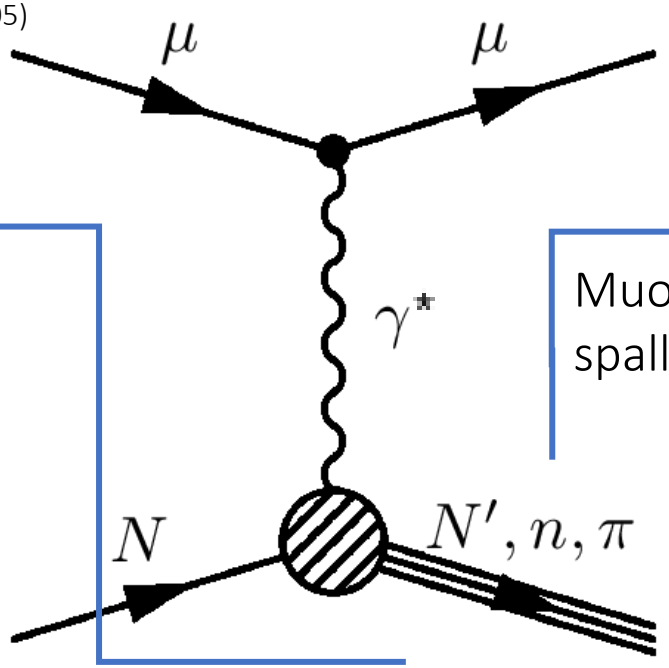
$\beta - n$ *emitter*

$^{9}Li \rightarrow {}^{9}Be^{*} + \boldsymbol{e^{-}} + \bar{\nu}_e \rightarrow {}^{8}Be + \boldsymbol{n}$

$\tau \simeq 257ms$

$^{8}He \rightarrow {}^{8}Li^{*} + \boldsymbol{e^{-}} + \bar{\nu}_e \rightarrow {}^{7}Li + \boldsymbol{n}$

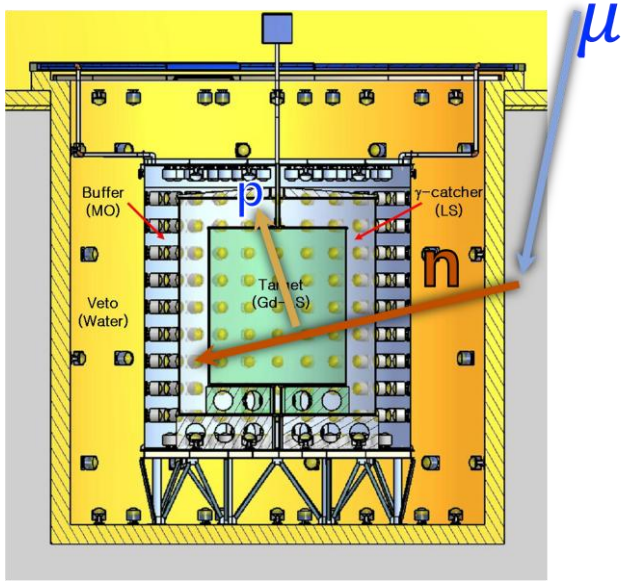
$\tau \simeq 172ms$



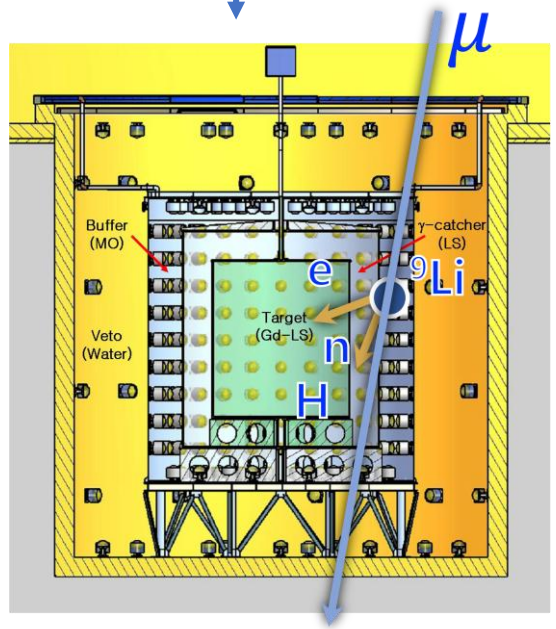
n_{fast}

Interaction in surrounding rock / detector

Muon-induced spallation on ^{12}C



Fast neutron background



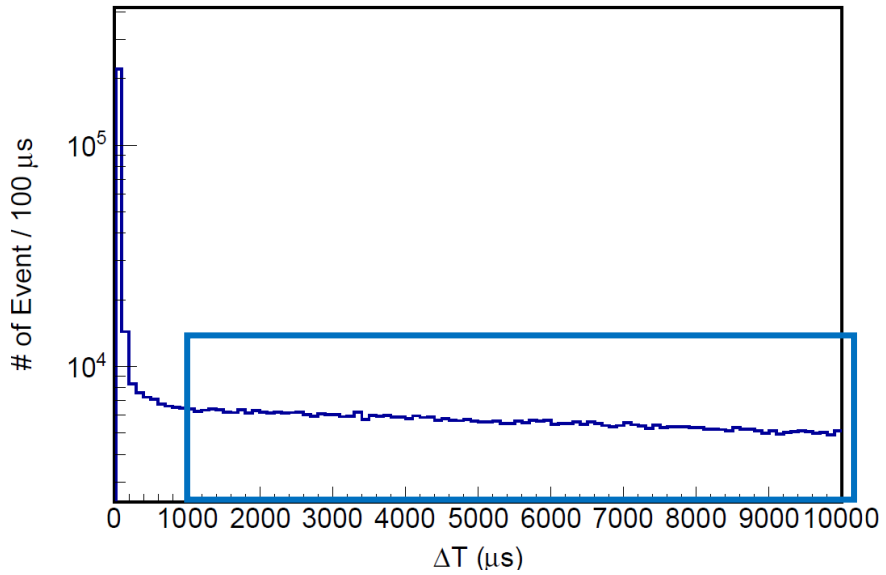
Li/He background

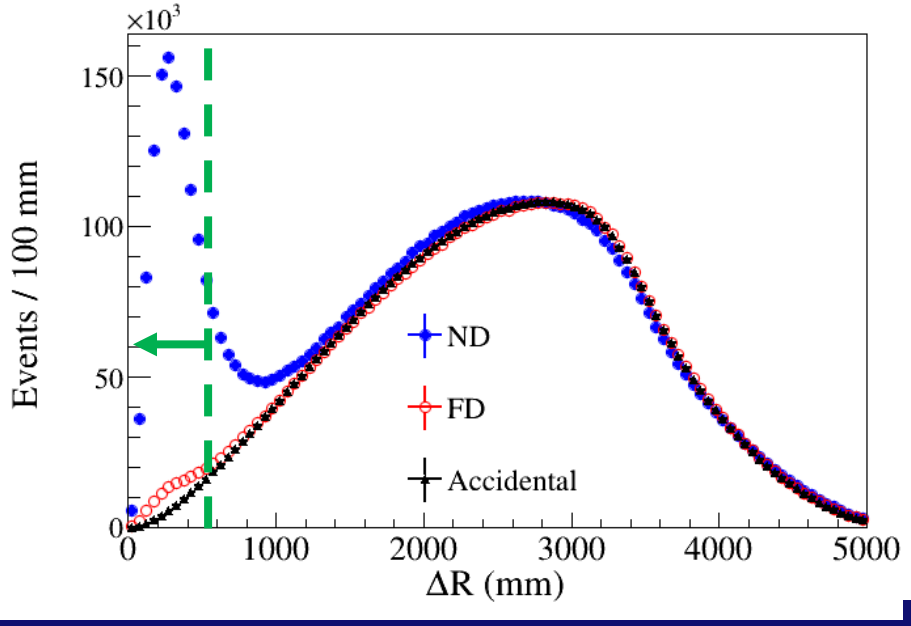
Backgrounds

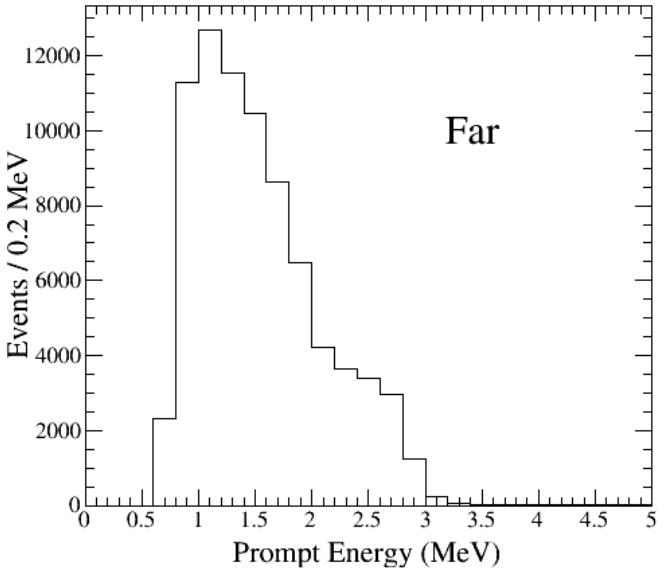
Accidental background

- Random coincidence of two uncorrelated events can mimic an IBD event.
  - Accidental events have no temporal and spatial correlation.

➢ Estimation
- Obtain the energy and ΔR spectra from the sample with $\Delta T > 1\ ms$
- Fit the control sample ΔR distribution to that of IBD candidates at $\Delta R > 2{,}000\ mm$
- Estimate the accidental background at $\Delta R < 450\ mm$





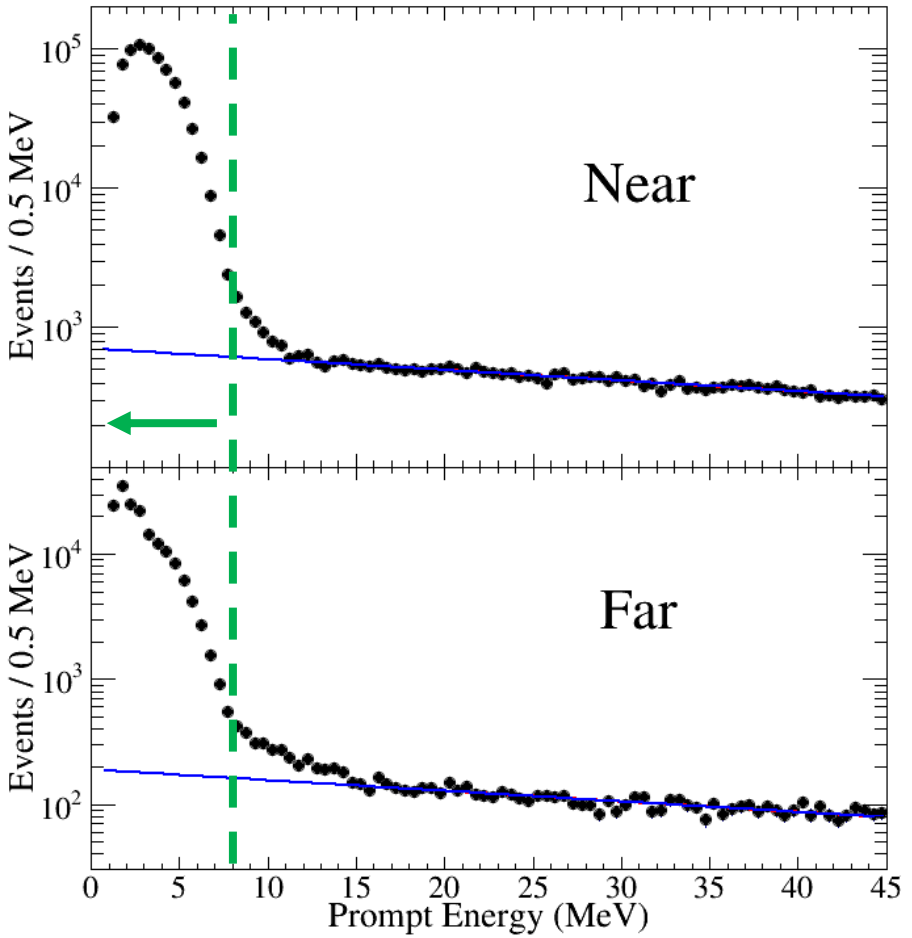


Backgrounds

Fast neutron background

- A fast neutron produces a proton recoil followed by neutron capture
  - The proton-recoil signal extends to high energies

➢ Estimation
- Obtain the control sample by extending the prompt energy up to 60 MeV
- Fit the high-energy spectrum with an exponential function
- Extrapolate the fitted spectrum to the IBD energy region, 1.2 ~ 8 MeV

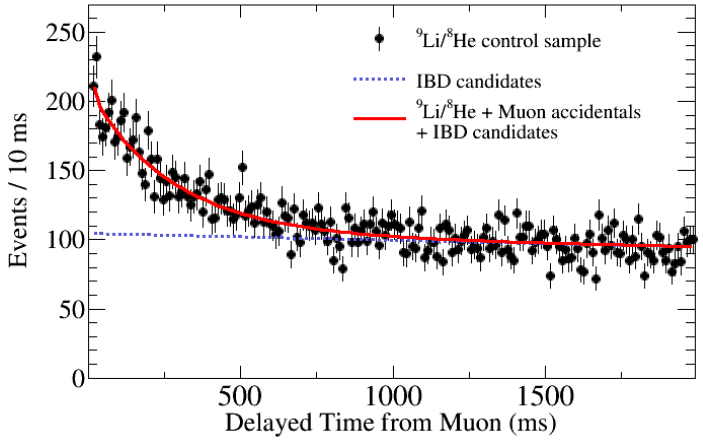


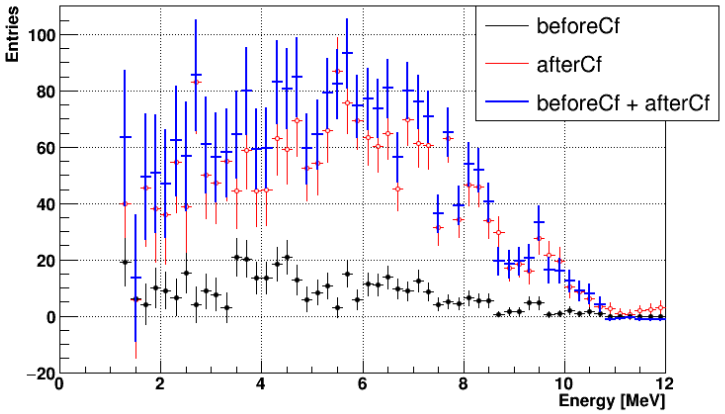
Backgrounds

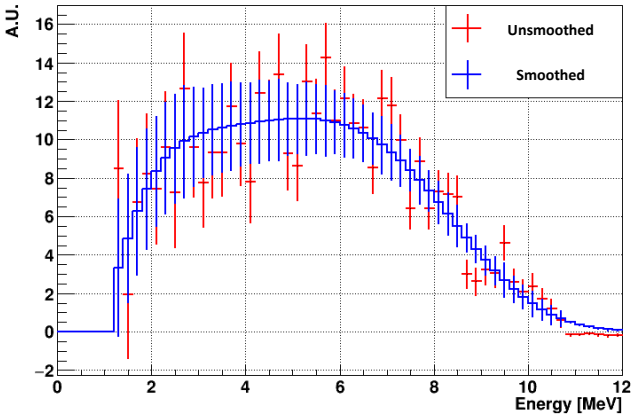
^{9}Li/ ^{8}He background

- Cosmogenic $\beta - n$ decays produce a correlated prompt-delayed pair
  - The $\beta - n$ decays are time-correlated with the preceding muon

➢ Template generation
- Obtain the control sample by relaxing the shower muon veto
- Fit the ΔT_{μ} and subtract the temporally uncorrelated component
- Smooth the template to reduce bin-to-bin fluctuations due to the limited statistics







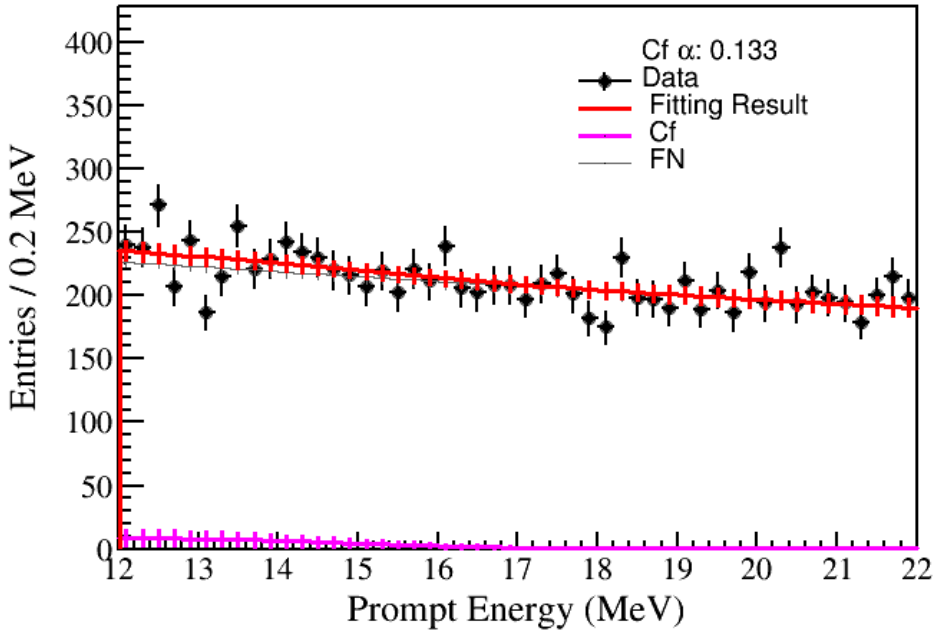
Backgrounds

^{252}Cf background

- Spontaneous fission produces multiple neutrons that can mimic IBD events.

➢ Template preparation
- Adopt the Cf template from the n-Gd analysis due to limited n-H statistics

➢ Preliminary estimation
- Use the fast neutron control sample extended to high energy region
- Fit the spectrum with fast neutron + Cf components at $12 < E_p < 22$ MeV
- Obtain the preliminary Cf background rate



Backgrounds

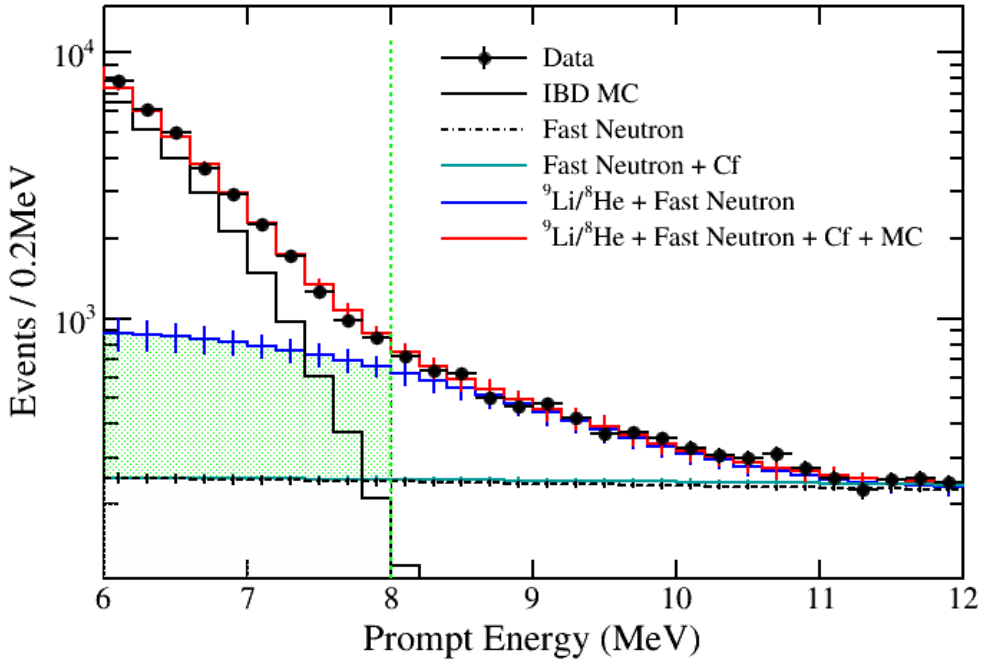
Li/He and Cf backgrounds

- Li/He and Cf backgrounds extend to the high energy region of the IBD candidate spectrum.

➢ Estimation

- Subtract the accidental background from the IBD candidate spectrum
- Fit the spectrum at $8 < E_p < 12$ MeV
  - beforeCf: IBD MC + Fast neutron + Li/He
  - afterCf: IBD MC + Fast neutron + Li/He + Cf

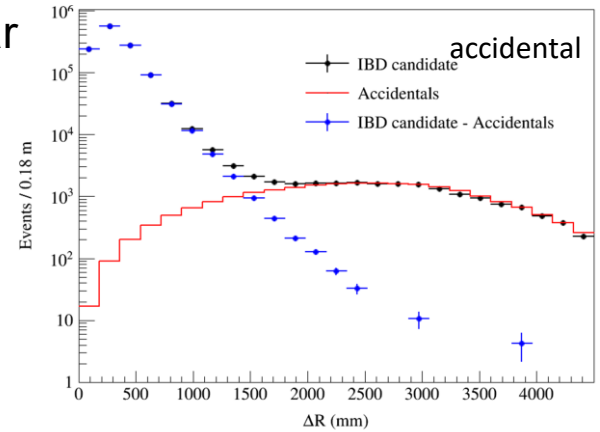
- Determine the Li/He background for each period and the residual Cf contribution for the afterCf period

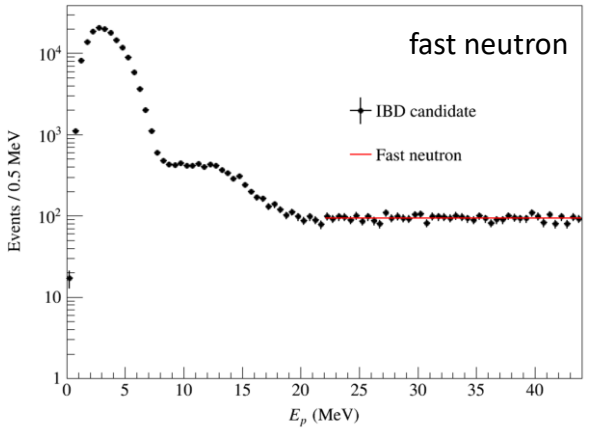


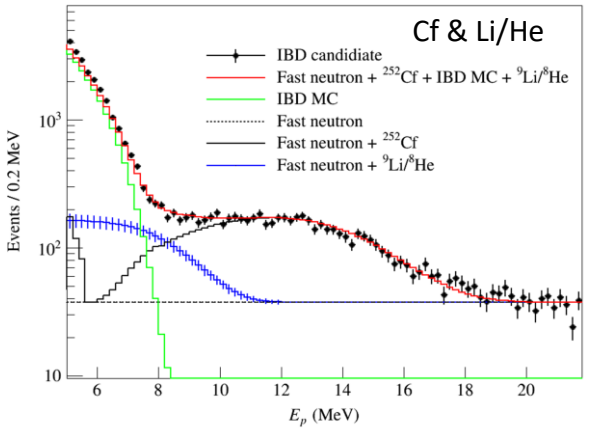
nGd IBD Candidate Sample & Background Estimation

- 1.2M (0.14M) $\bar{\nu}_e$ candidate events are observed in the near (far) detector.

- The total background rates :
  - near : 9.08±0.18 [events/day] (2.5%)
  - far : 2.06±0.13 [events/day] (5.3%)





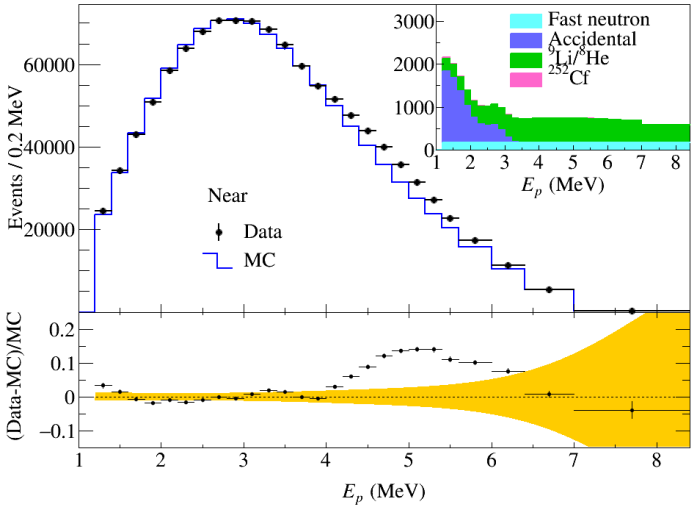


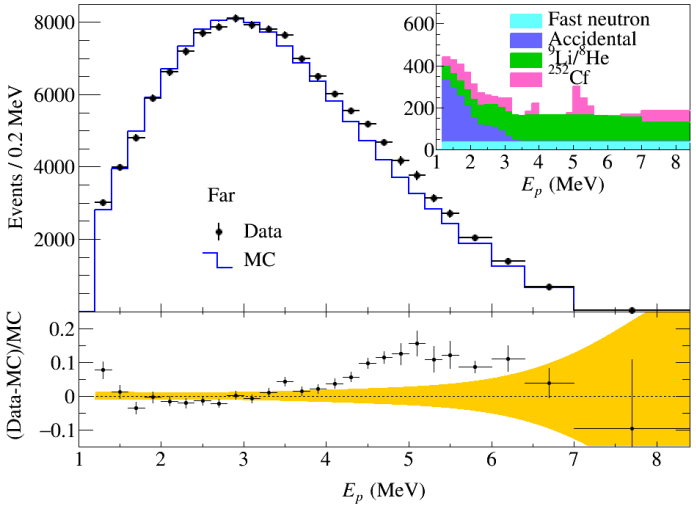
Detector	Near	Far
IBD rate	366.47 ± 0.33	38.70 ± 0.10
after background subtraction	357.39 ± 0.38	36.64 ± 0.16
total background rate	9.08 ± 0.18	2.06 ± 0.13
live time [days]	3307.25	3737.85

measured IBD and estimated background rates with
$1.2 < E_p < 8.0$ [MeV], given per day

nGd IBD Prompt Spectrum

- A shape comparison between the observed IBD prompt spectrum and the prediction from a reactor $\bar{\nu}_e$ model
  - data : observed IBD prompt spectrum after background subtraction
  - MC : prediction with best-fit oscillation
- The fractional difference between data and prediction in the lower panel
- A clear discrepancy between the observed and the predicted spectral shapes in the region of 5 [MeV]



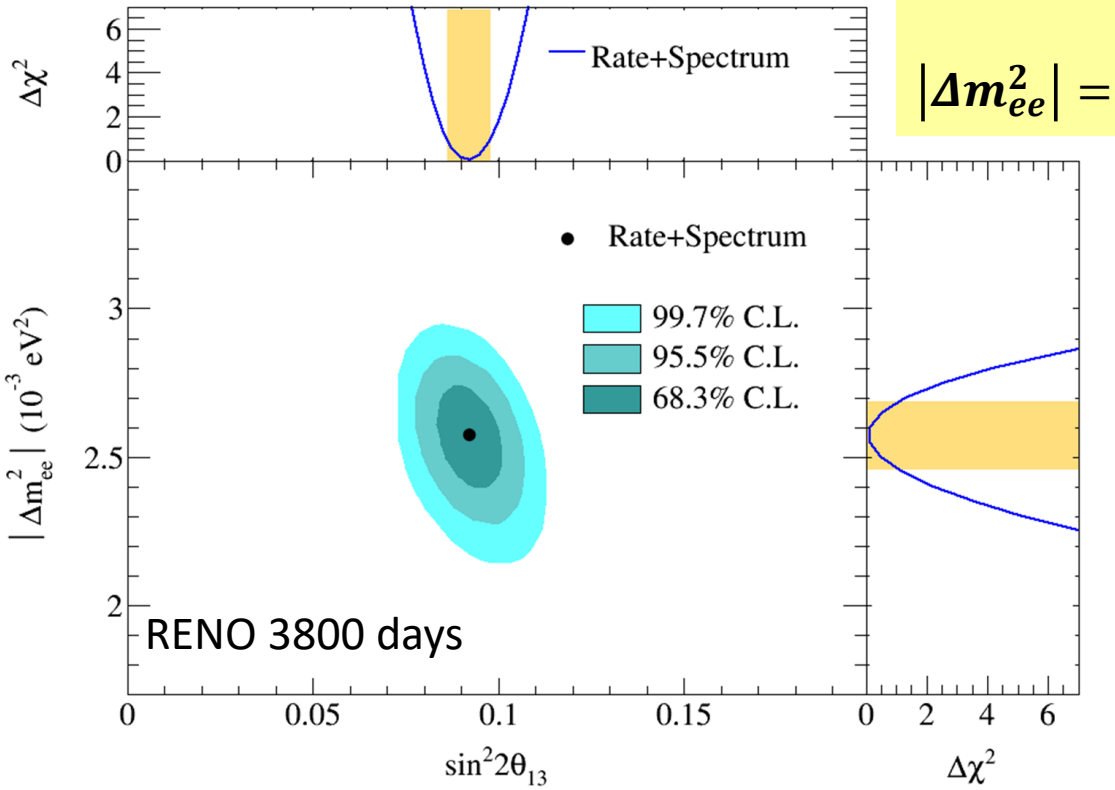


nGd Results of $|\Delta m^2_{ee}|$ and θ_{13}

Based on the measured far-to-near ratio of prompt spectra from the 3800-day sample,

$$\boldsymbol{sin^2 2\theta_{13} = 0.0920\ ^{+0.0044}_{-0.0042}(stat.)\ ^{+0.0041}_{-0.0041}(syst.)}$$ (6.4% precision)

$$\boldsymbol{|\Delta m^2_{ee}| = 2.57\ ^{+0.10}_{-0.11}(stat.)\ ^{+0.05}_{-0.05}(syst.)[\times 10^{-3} eV^2]}$$ (4.5% precision)



source of the systematic uncertainty

	Δm^2_{ee} $[10^{-3} eV^2]$	$sin^2 2\theta_{13}$ []
reactor	-	± 0.0003
detection efficiency	-	± 0.0032
energy scale	± 0.05	± 0.0009
backgrounds	± 0.02	± 0.0015

PHYSICAL REVIEW D **111,** 112006 (2025)

Measurement of reactor antineutrino oscillation parameters using the full 3800-day dataset of the RENO experiment

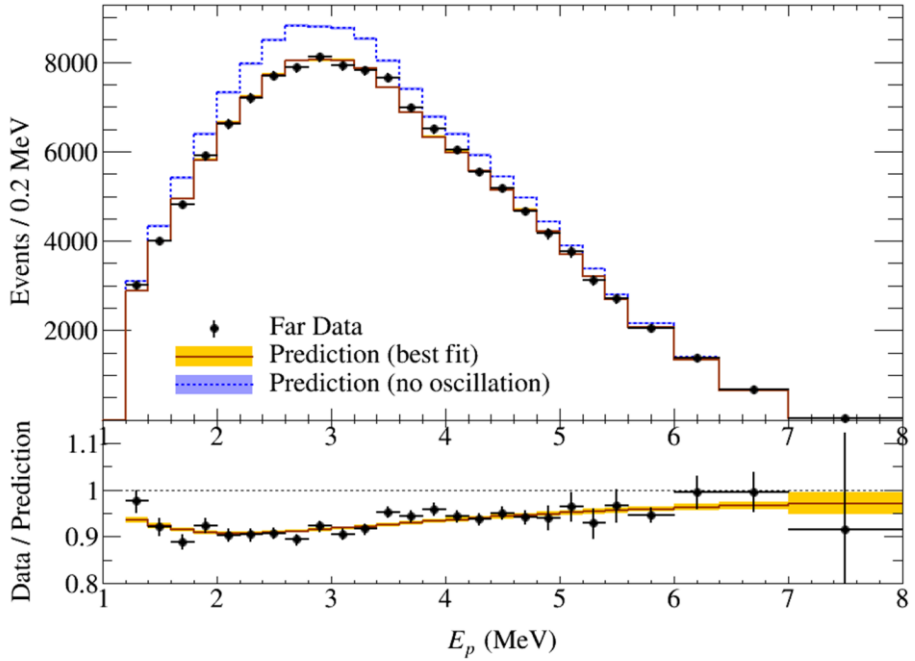
S. Jeon,[1,2,3] H. I. Kim,[2] J. H. Choi,[1] H. I. Jang,[4] J. S. Jang,[5] K. K. Joo,[6] D. E. Jung,[6] J. G. Kim,[7] J. H. Kim,[7] J. Y. Kim,[6] S. B. Kim,[2] S. Y. Kim,[6] W. Kim,[8] E. Kwon,[7] D. H. Lee,[9] H. G. Lee,[6] W. J. Lee,[2] I. T. Lim,[6] D. H. Moon,[6] M. Y. Pac,[1] J. S. Park,[8] R. G. Park,[6] H. Seo,[2] J. W. Seo,[7] C. D. Shin,[9] B. S. Yang,[6] J. Yoo,[2] S. G. Yoon,[2] I. S. Yeo,[1] and I. Yu[7]

(RENO Collaboration)

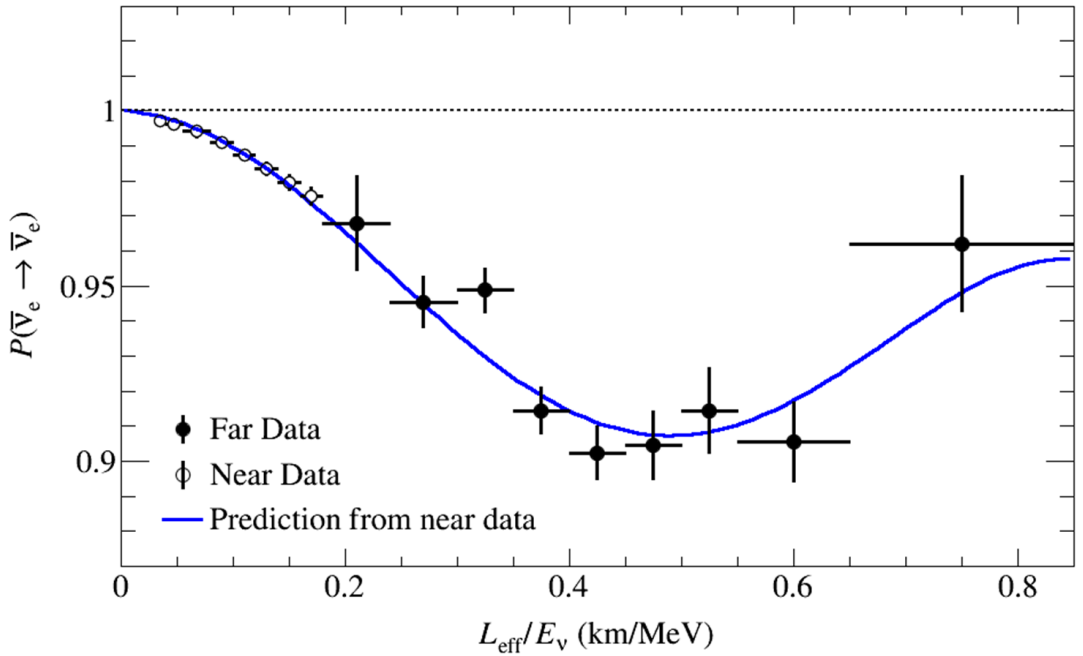
Phys. Rev. D 111, 112006 (2025)

nGd Energy & L/E Dependent $\bar{\nu}_e$ Oscillation

Energy-dependent disappearance of reactor $\bar{\nu}_e$



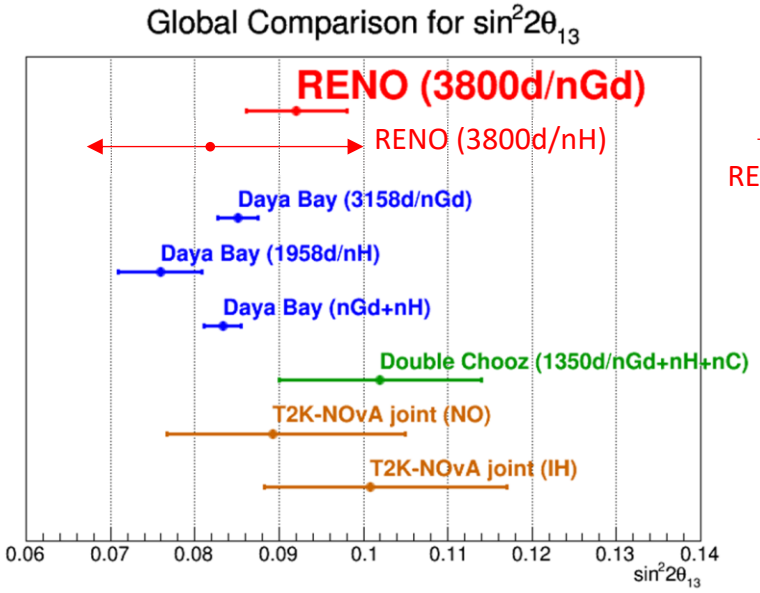
Observed L/E-dependent oscillation



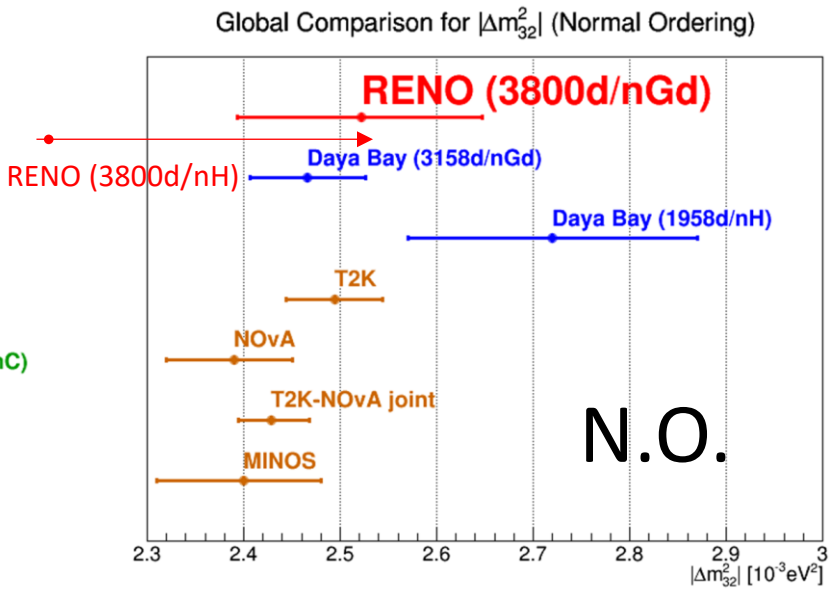
$$P(\bar{\nu}_e \to \bar{\nu}_e) \approx 1 - sin^2 2\theta_{13} sin^2\left(\Delta m^2_{ee} \frac{L}{4E_\nu}\right)$$

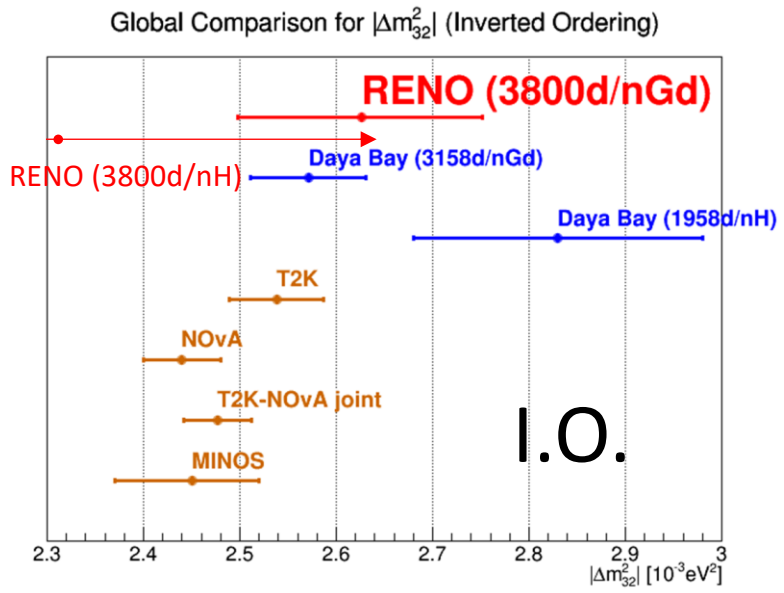
Global Comparison

$sin^2 2\theta_{13}$

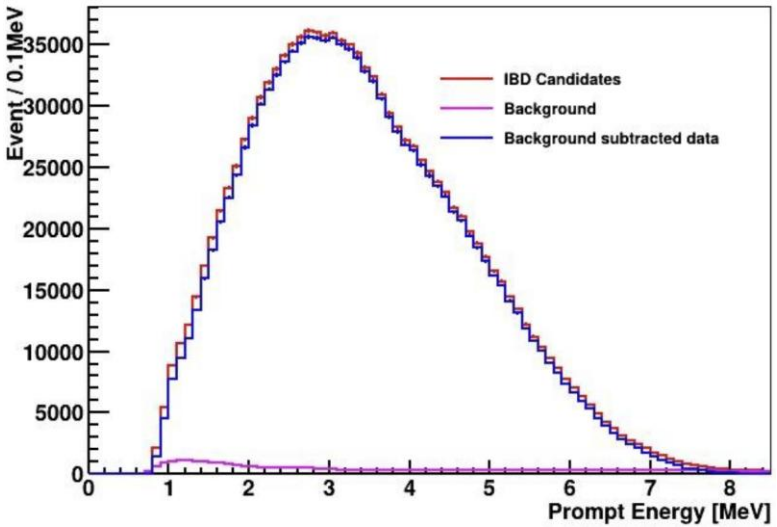


$\left|\Delta m^2_{32}\right|$

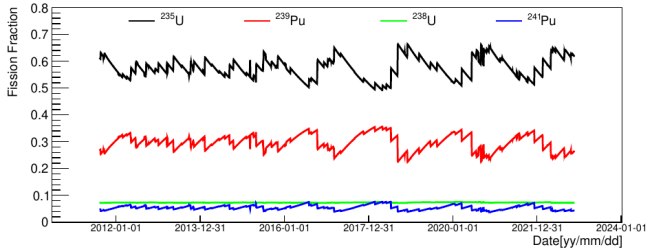




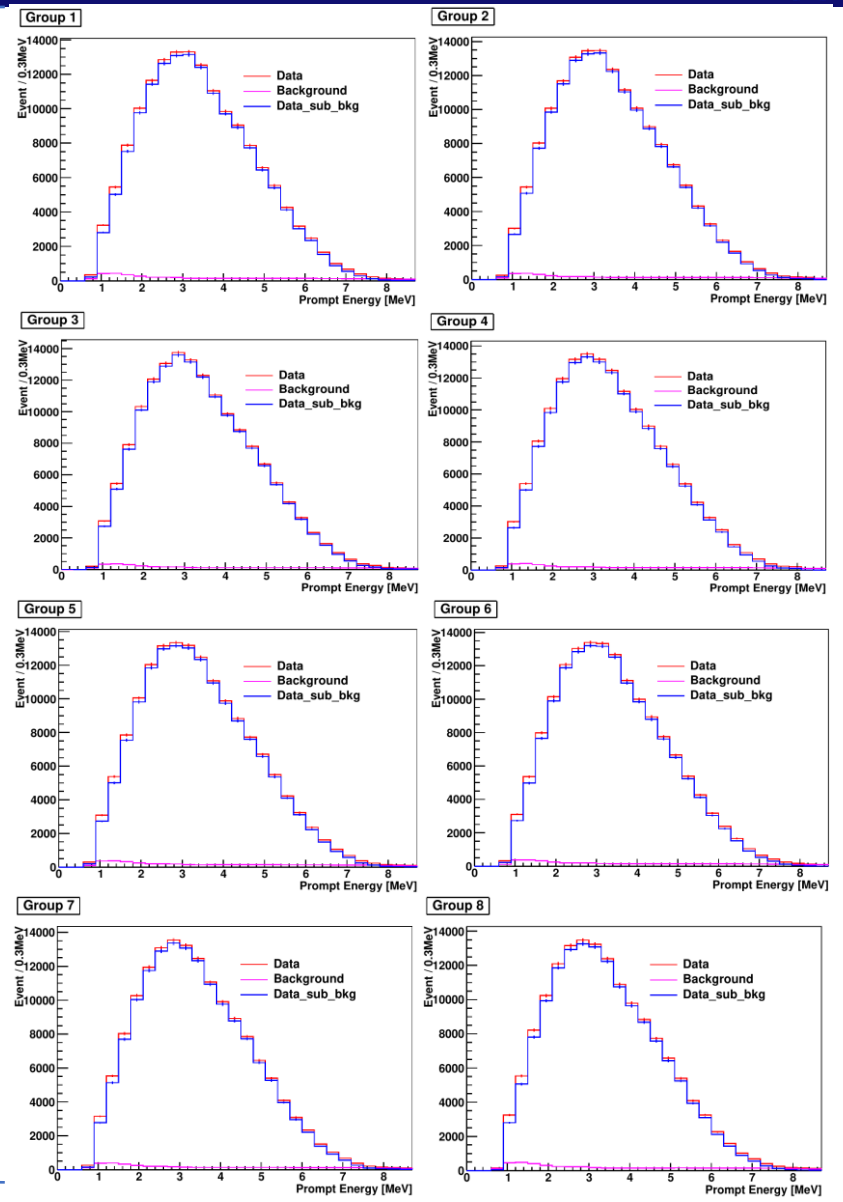
nGd Analysis



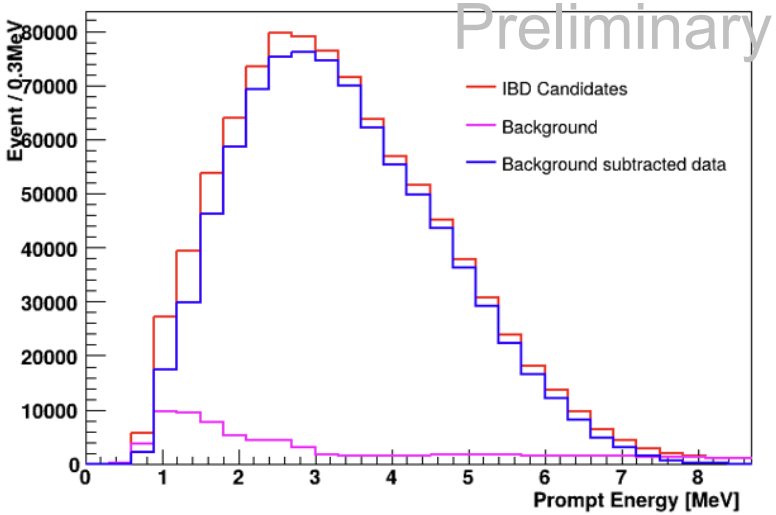
Fuel cycle



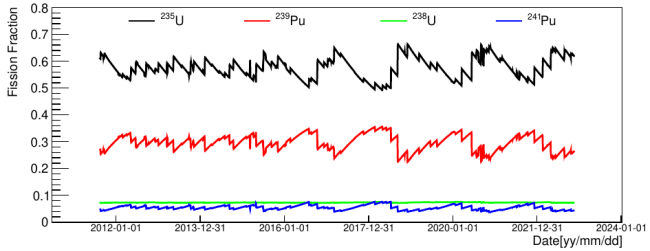
	Livetime	IBD Candidates	Background	IBD
Group 1	477.986	154787 ± 393.430	5279.24 ± 161.703	150099 ± 425.365
Group 2	378.459	155440 ± 394.259	4480.52 ± 150.417	151467 ± 421.978
Group 3	360.300	155379 ± 394.181	4255.00 ± 146.556	151581 ± 420.545
Group 4	385.094	155429 ± 394.245	5237.82 ± 166.629	150782 ± 428.012
Group 5	389.721	154753 ± 393.387	4837.37 ± 300.806	150485 ± 495.214
Group 6	404.933	155533 ± 394.377	5102.73 ± 157.469	150964 ± 424.652
Group 7	417.752	115609 +- 340.013	4933.30 ± 165.060	150448 ± 426.661
Group 8	504.302	154795 ± 393.440	5786.41 ± 168.153	149894 ± 428.113



nH Analysis (Preliminary)



Fuel cycle



	Livetime	IBD Candidates	Background	IBD
Group 1	476.409	109233 ± 330.504	8218.75 ± 390.491	101014 ± 511.582
Group 2	377.002	113060 ± 336.244	6819.16 ± 329.978	106241 ± 471.111
Group 3	359.549	113428 ± 336.791	6854.75 ± 341.926	109010 ± 484.338
Group 4	385.090	113873 ± 337.451	7045.53 ± 339.678	106827 ± 478.805
Group 5	387.615	114644 ± 338.591	6930.43 ± 347.620	107714 ± 485.274
Group 6	403.686	113886 ± 337.470	7157.56 ± 366.895	106728 ± 498.496
Group 7	414.359	115609 ± 340.013	7574.85 ± 348.427	108034 ± 486.837
Group 8	503.543	110874 ± 332.977	9168.80 ± 429.073	101705 ± 543.119

