NEOS-II updates

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on behalf of NEOS-II Collaboration

CENTER FOR UNDERGROUND PHYSICS ibs

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Neutrino Experiment for Oscillation at SBL

Key features

- A single, homogeneous IBD detector at a fixed distance (~24 m) from a commercial reactor.
- No self *L* resolution
- Oscillation analysis depending on existing model/longer baseline data.

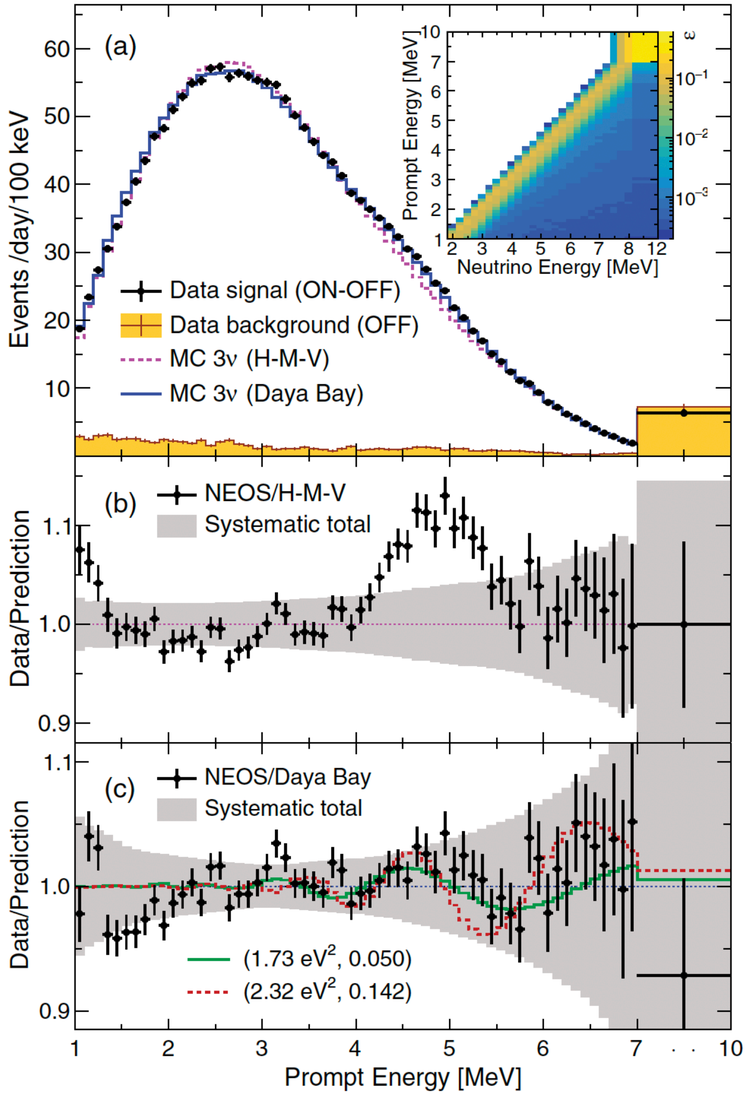
Outline

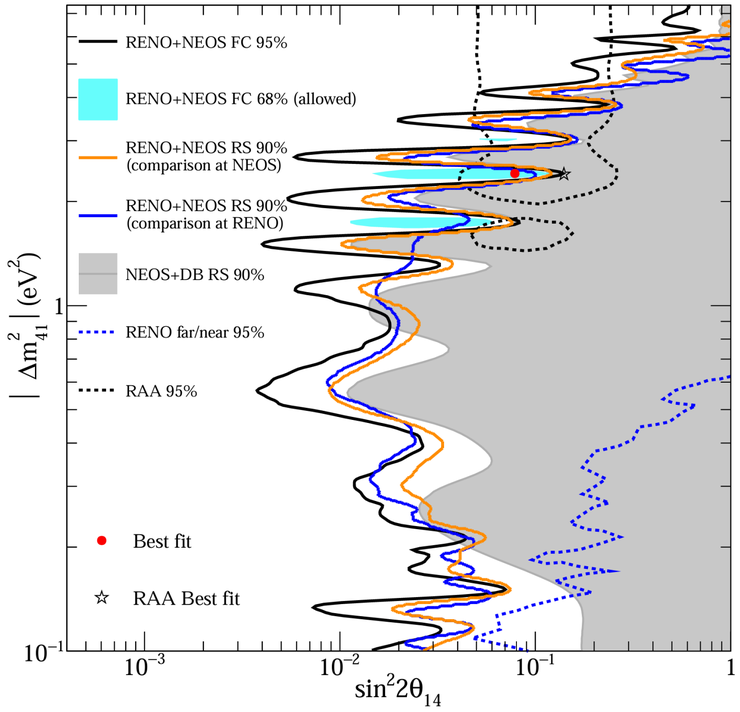
- Reminder: NEOS-I and experimental apparatus
- NEOS-II goals
- NEOS-II result updates:
  - Extraction of antineutrinos from ^{235}U and ^{239}Pu.
  - Short baseline oscillation

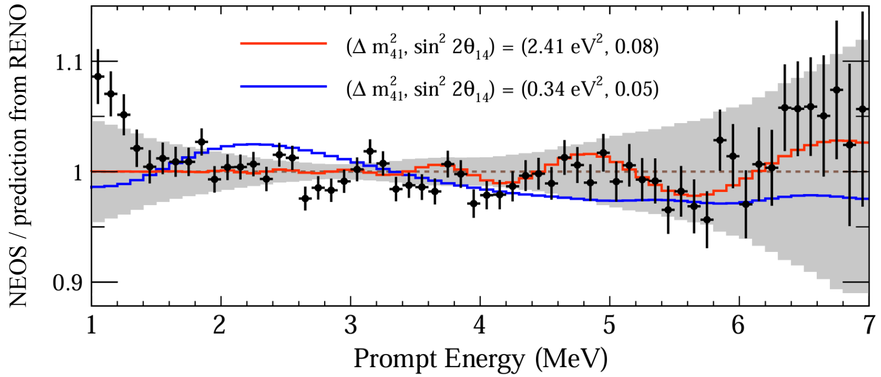
NEOS-I result on SBL oscillation

PRL 118 (2017) 121802
PRD 105 (2022) L111101

Comparison with Huber-Mueller, Daya Bay, and RENO



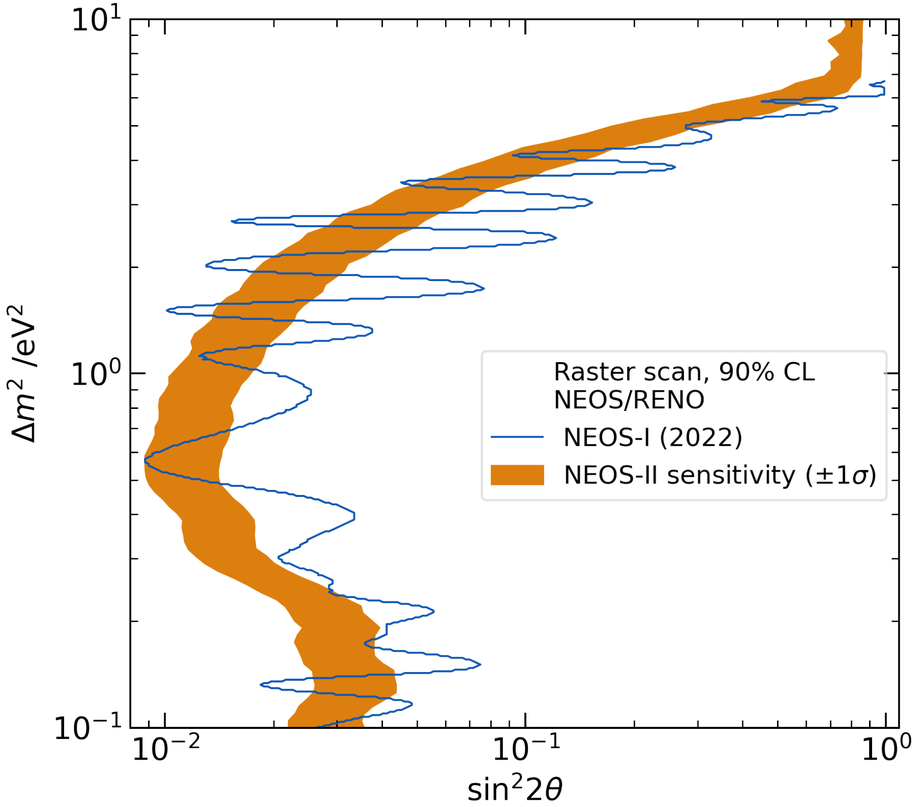


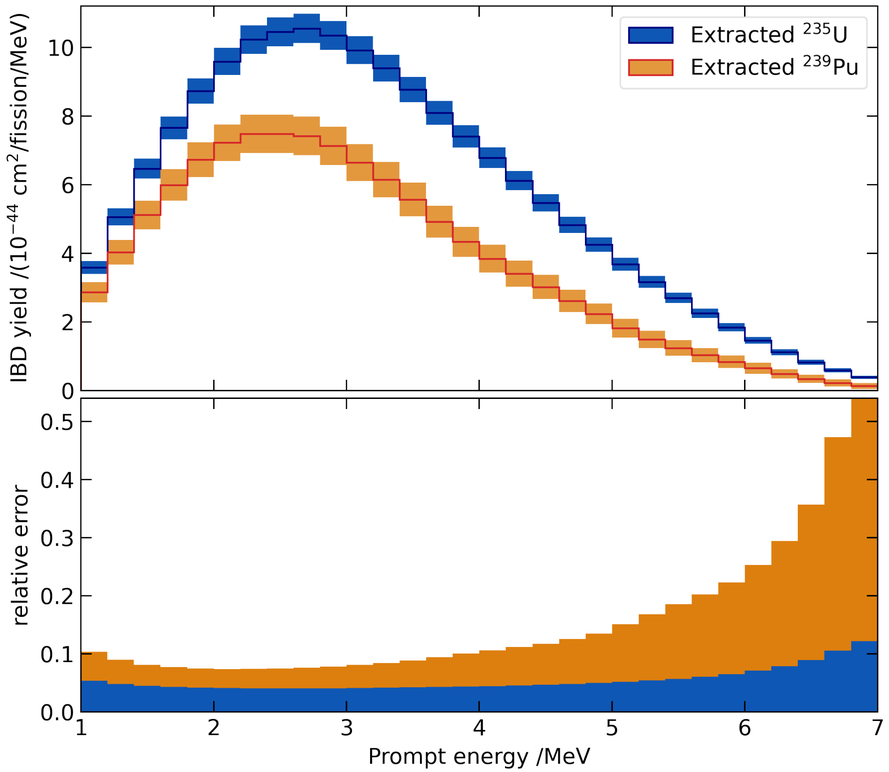


- Reactor ON: 180 days, OFF: 46 days.
- Daily IBD candidate rate: 1977 (ON) / 85 (OFF), S/B~22.
- vs Daya Bay reference:
  - Best fit at: (0.05, 1.7 eV²) $\Delta\chi^2$ = 6.5, p-value = 22%.
- vs RENO reference:
  - Considering oscillation at RENO, too.
  - Best fit at: (0.08, 2.4 eV²) $\Delta\chi^2$ = 8.4, p-value = 8.2%.
- Distortion or “bump” not totally disappeared after the Daya Bay/ RENO normalization.
  - Differences in fission fractions?

From NEOS-I to NEOS-II

Utilizing a full fuel cycle of a sole commercial reactor

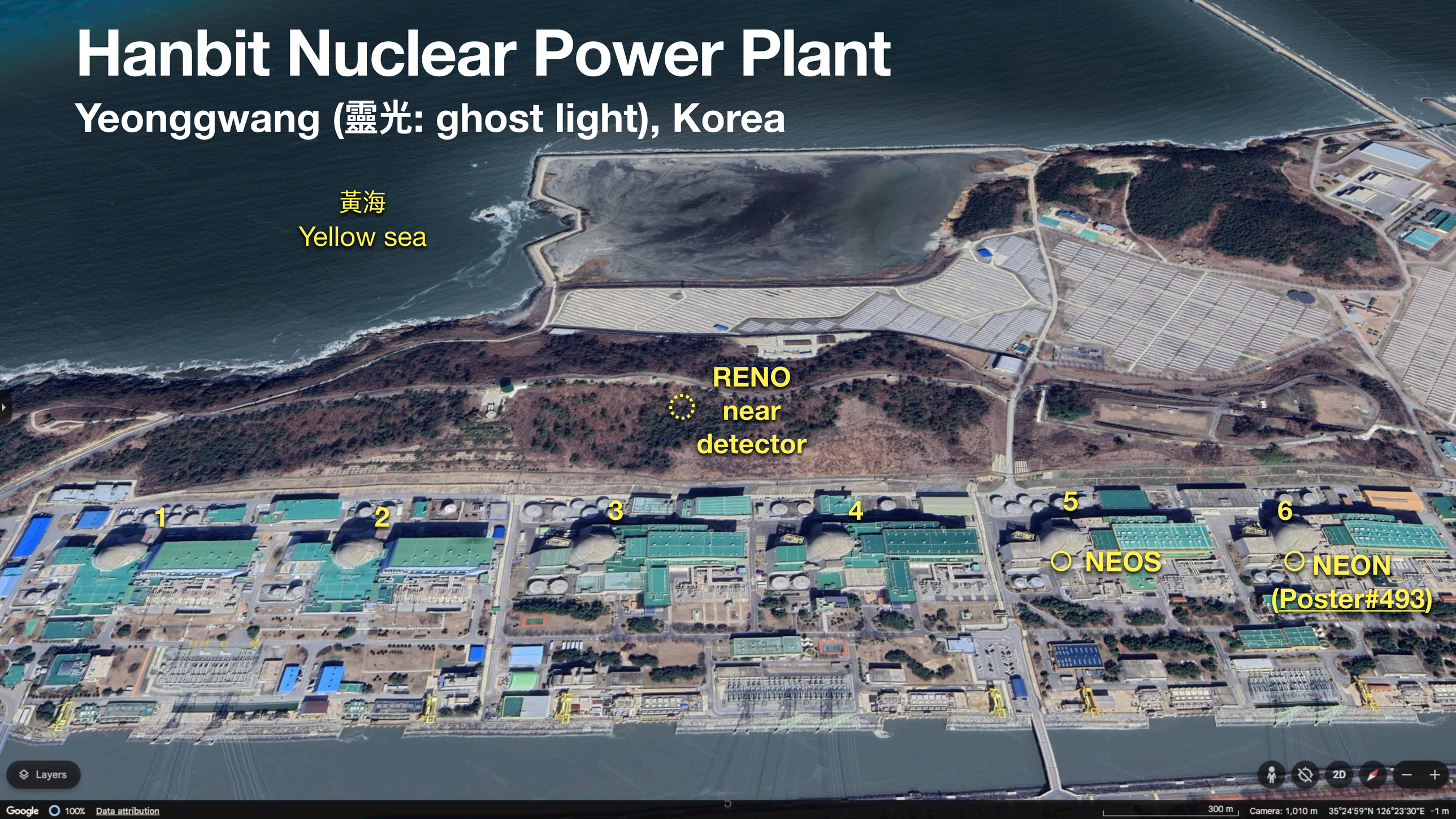




- Improving sensitivity for the SBL oscillation: adding more significance to the NEOS-I best fit(s), or to find out that it was an statistical fluctuation?
- Reactor-ν spectrum evolution in time: extraction of the primary isotopes' (^{235}U/^{239}Pu) contribution.

Hanbit Nuclear Power Plant

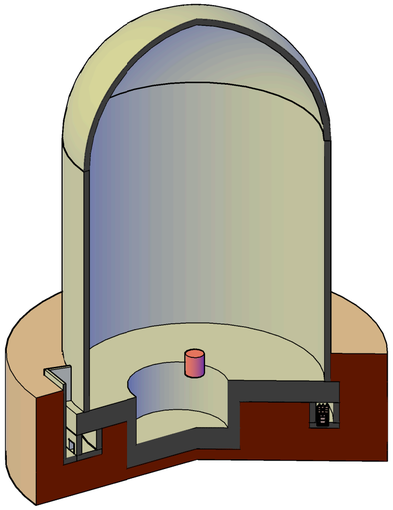
Yeonggwang (靈光: ghost light), Korea

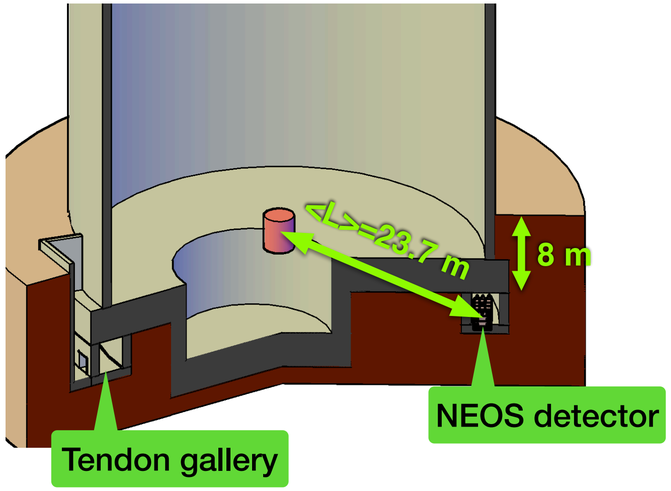


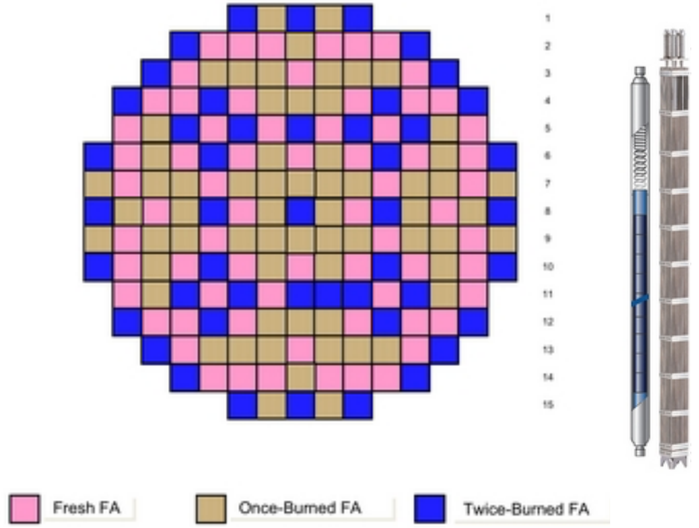
Neutrino source: Hanbit-5 reactor

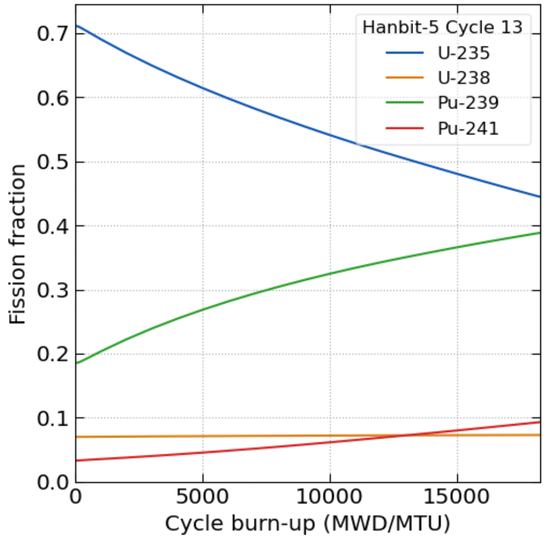
Low-enriched-uranium fuel / commercial / thermal power 2.8 GW

- A typical burn-up cycle takes about 1.5 years.
  - 1/3 of the fuel assemblies changed to new ones for a new cycle.
- Active core size— diameter: 3.1 m, height: 3.8 m.
- NEOS detector located 23.7 m away from the active core center.
- The nearest neighboring core, Hanbit-4&6, at 256 m away, less than 1% contribution of the main source.



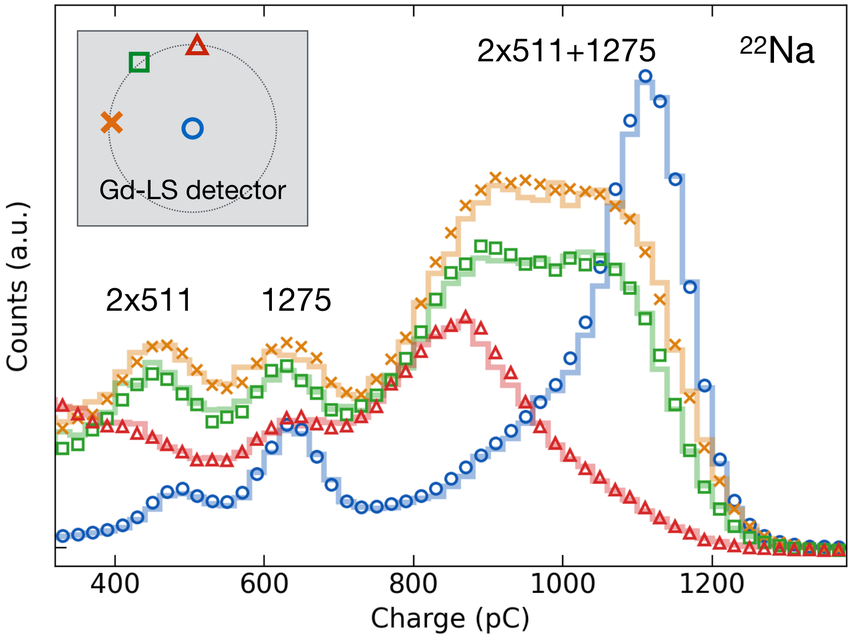






Detector

1 kL of homogeneous Gd-LS for IBD target + shield

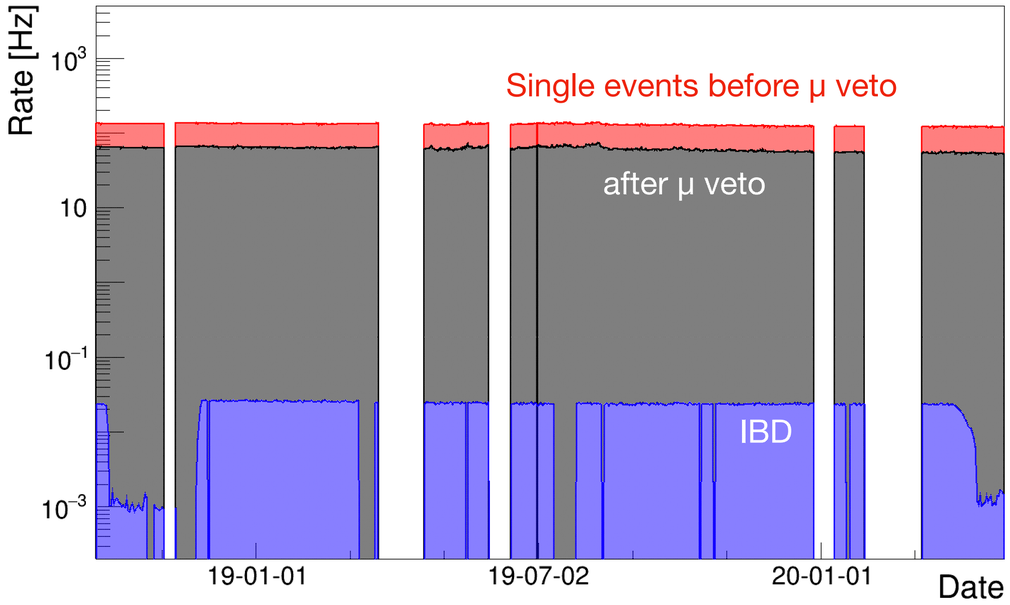


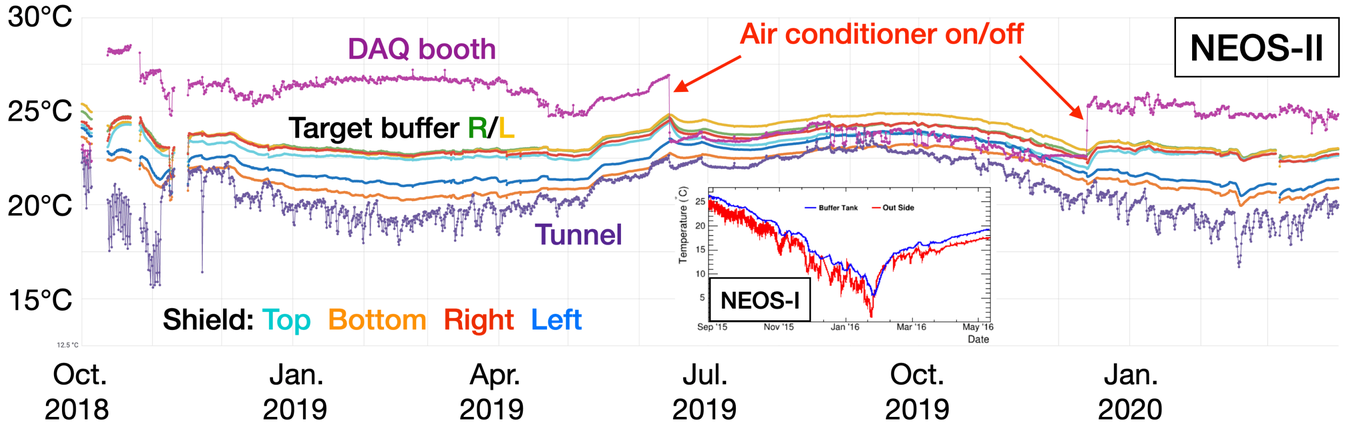
- Refurbished from NEOS-I detector.
  - Gd-LS newly produced—Gd: 0.5%wt.
  - LAB-based:Ultima Gold F = 9:1 for PSD.
- Target seen by 2×19 8-inch PMTs.
- B-PE (10 cm), Pb (10 cm), Muon counter.

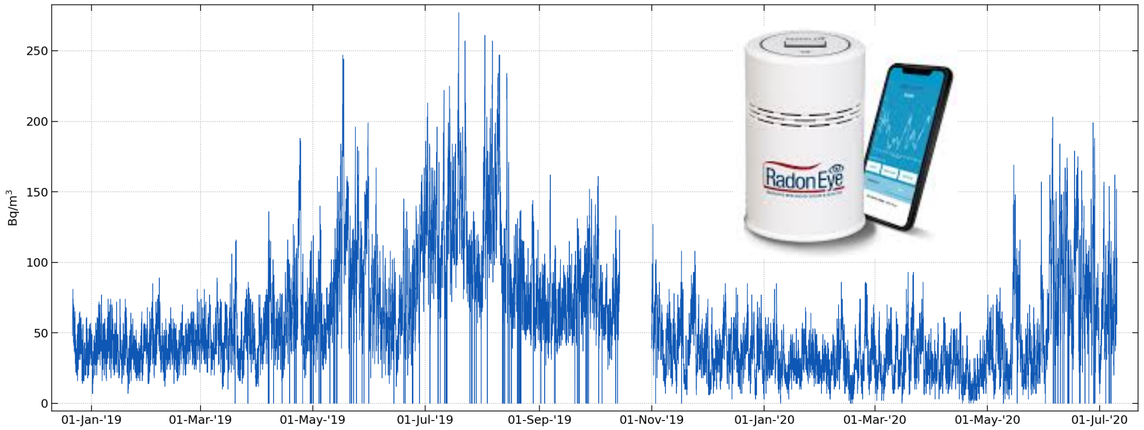
- Calibration: ^{22}Na, ^{60}Co, ^{137}Cs, PoBe, ^{252}Cf
- No γ-catcher layer:
  - Important to properly estimate γ-escaping effect.
  - 2-dimensional source calibration.

Data taking

- From Sep 2018 to Oct 2020.
- DAQ duty cycle ~ 90%.
  - Physics data for analysis ~ 80%:
    - With the reactor active (ON): 388 days,
    - With the reactor inactive (OFF): 43+74 days.
- Slow monitoring: temperature, radon in the air

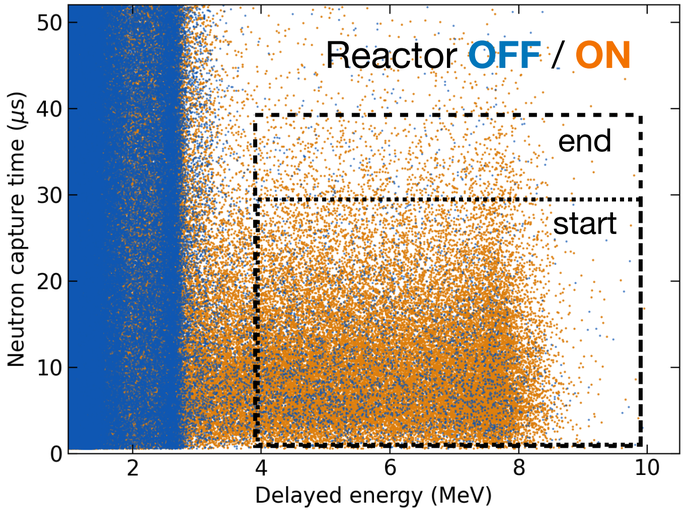


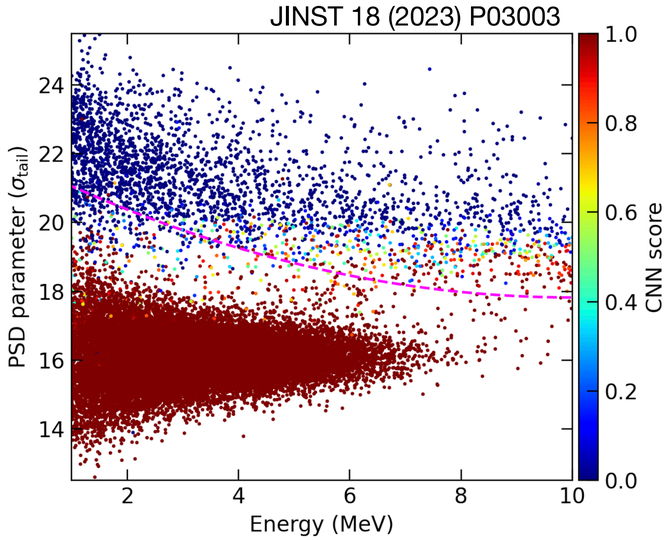


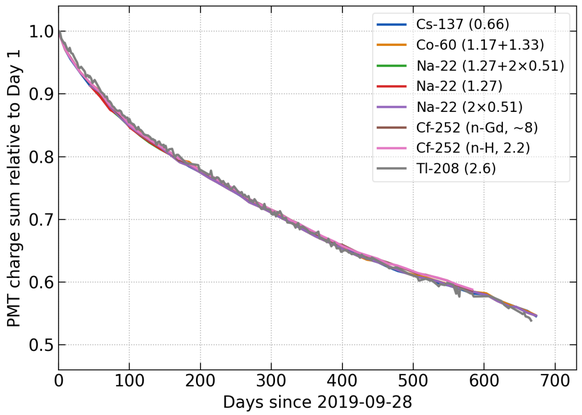


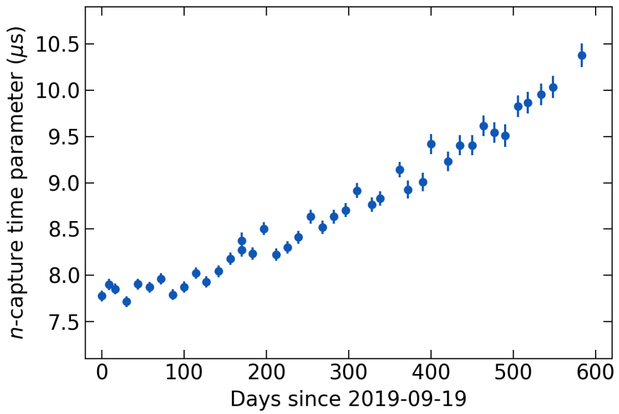
Analysis highlights

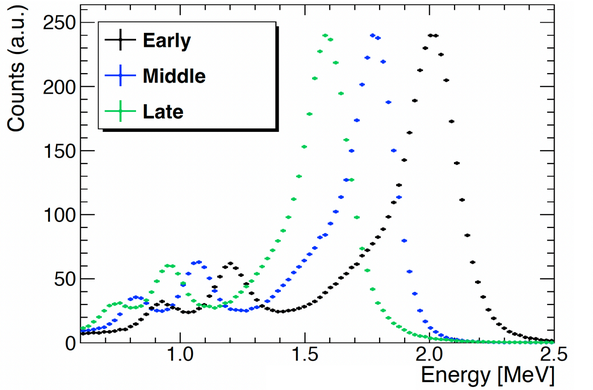
- Corrections for:
  - Non-uniform detector response
  - Light output decrease
- Energy smearing: σ~6.5% at 1 MeV.
- Cut evolution utilizing simulation
  - n-capture time and delayed energy
  - PSD: CNN for different data groups
  - Negligible effect on prompt shape





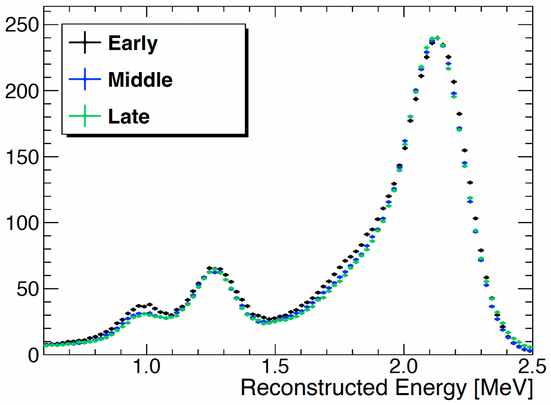




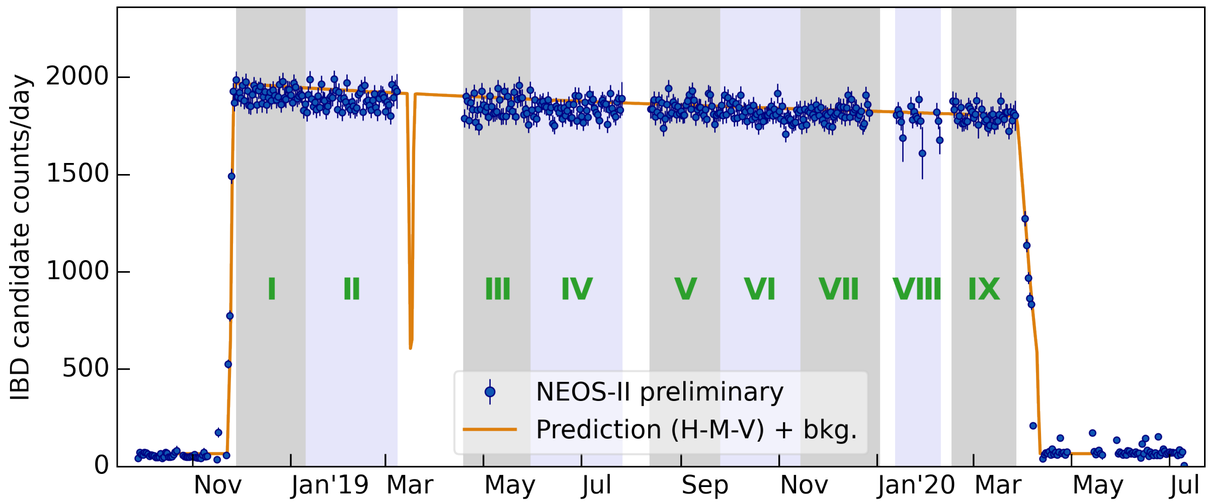


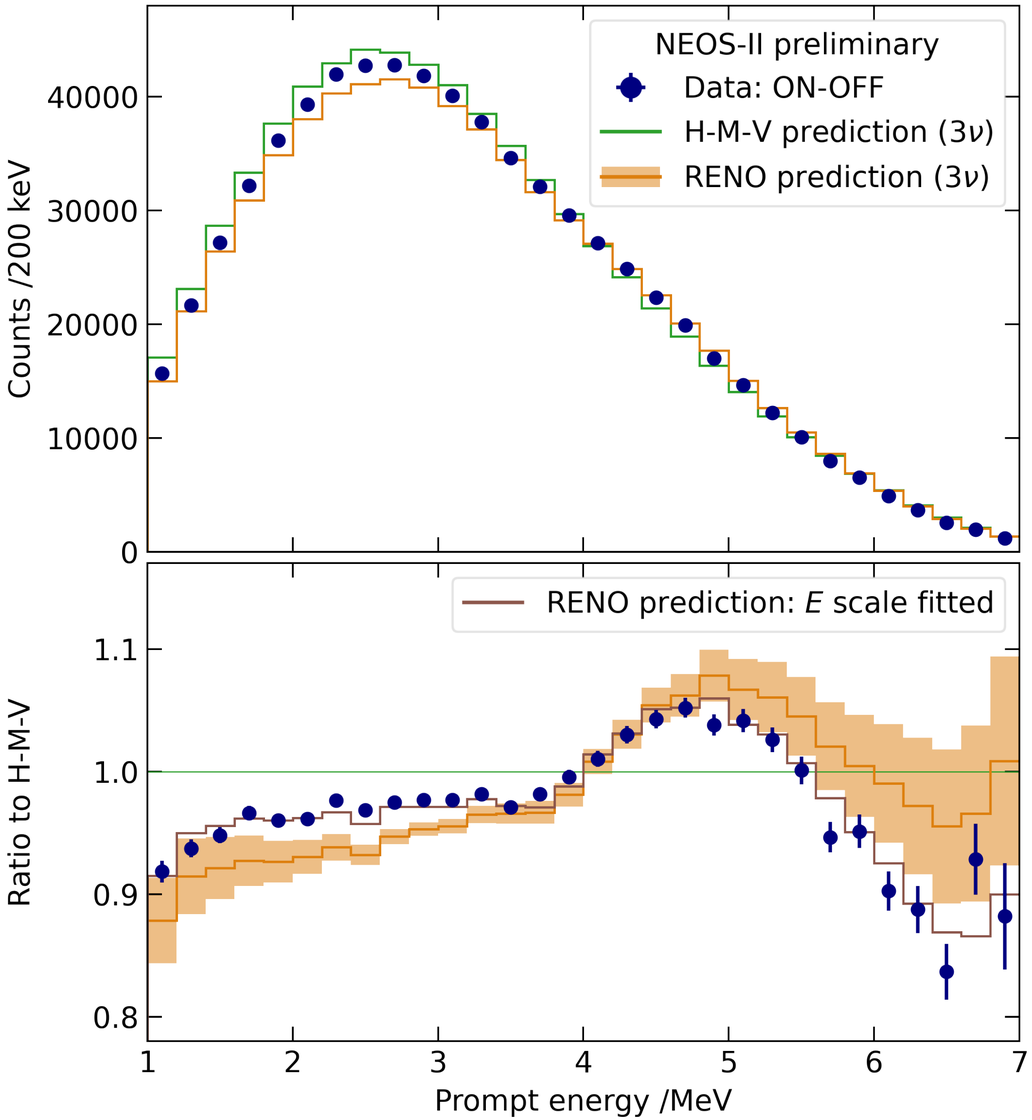
Gain correction+
energy smearing

^{22}Na source at center



IBD rate and spectrum

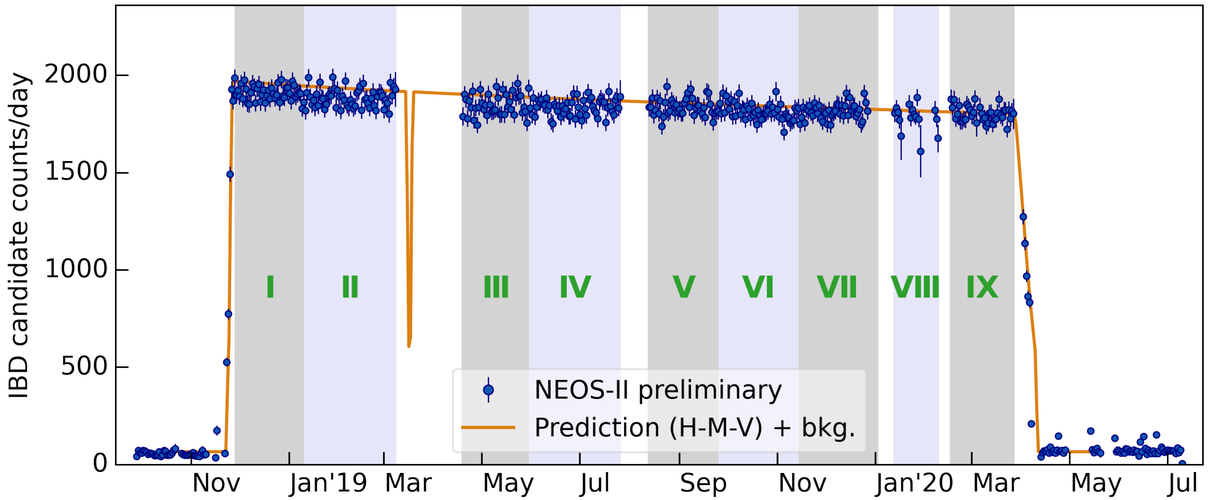




- IBD candidate event rate:
  - OFF: 67 /day
  - ON: ~1930 (start) ➔ ~1800 /day (end).
- Rate lies between Huber-Mueller-Vogel and RENO.
  - -2.7 ±2.5% of ϕ(Huber+Mueller)×σ(Vogel)
- Energy scale mismatch.
  - *E* scale parameter released in the oscillation analysis.

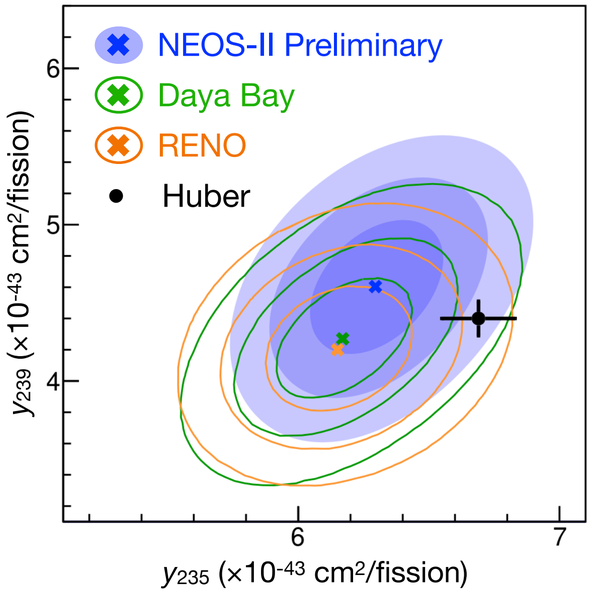
IBD yield and its evolution

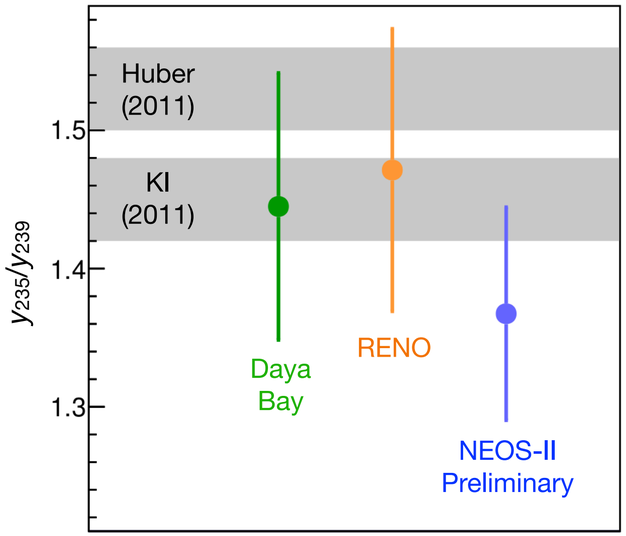
Extraction of ^{235}U, ^{239}Pu components



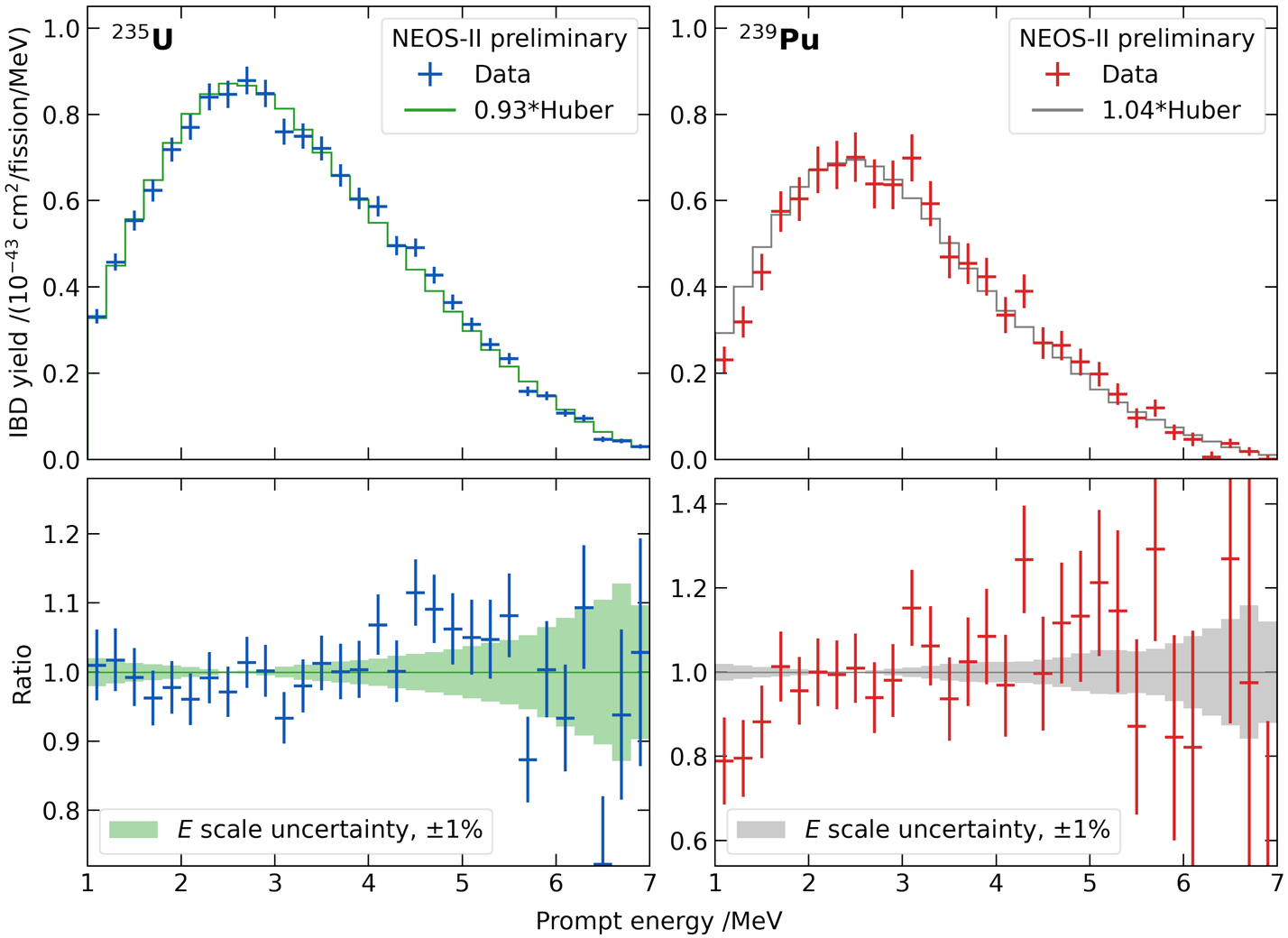
*Hanbit-6 contribution (~0.8%) is ignored in the prediction plot. Hanbit-3,4 were off.

- IBD yield (10^{-43} cm^2/fission):
  $y_{235} = 6.32 \pm 0.17$,
  $y_{239} = 4.70 \pm 0.28$.
- $y_{235}/y_{239} = 1.37 \pm 0.08$.
- y_{238}/y_{241}: constrained at Huber-Muellers ±10%.



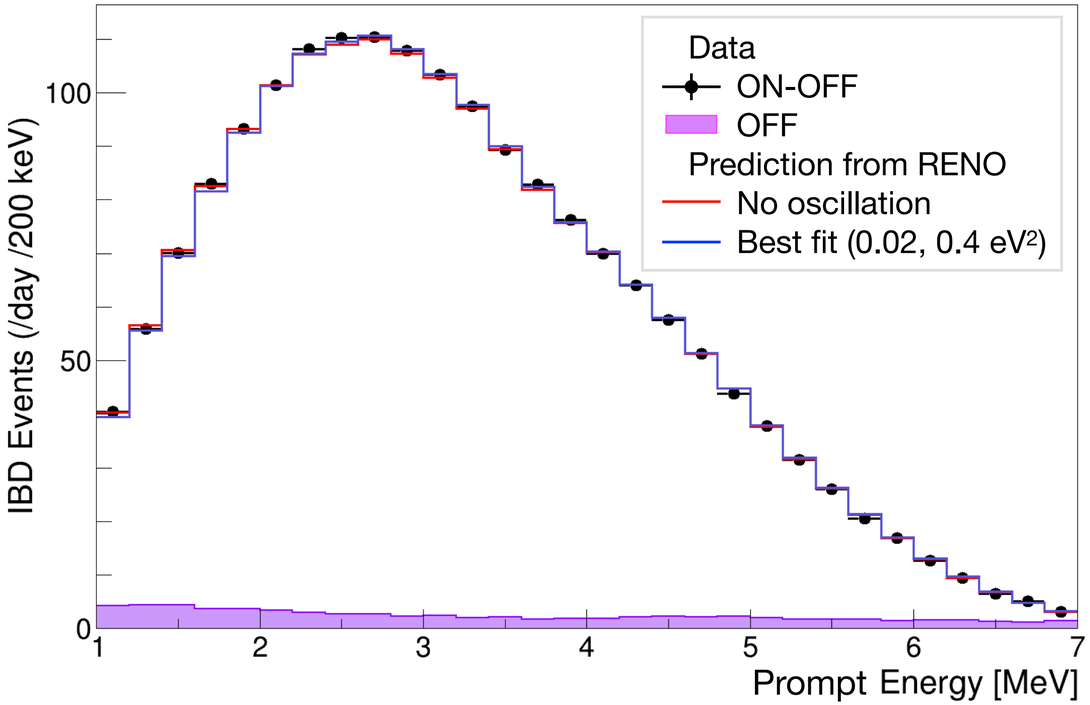


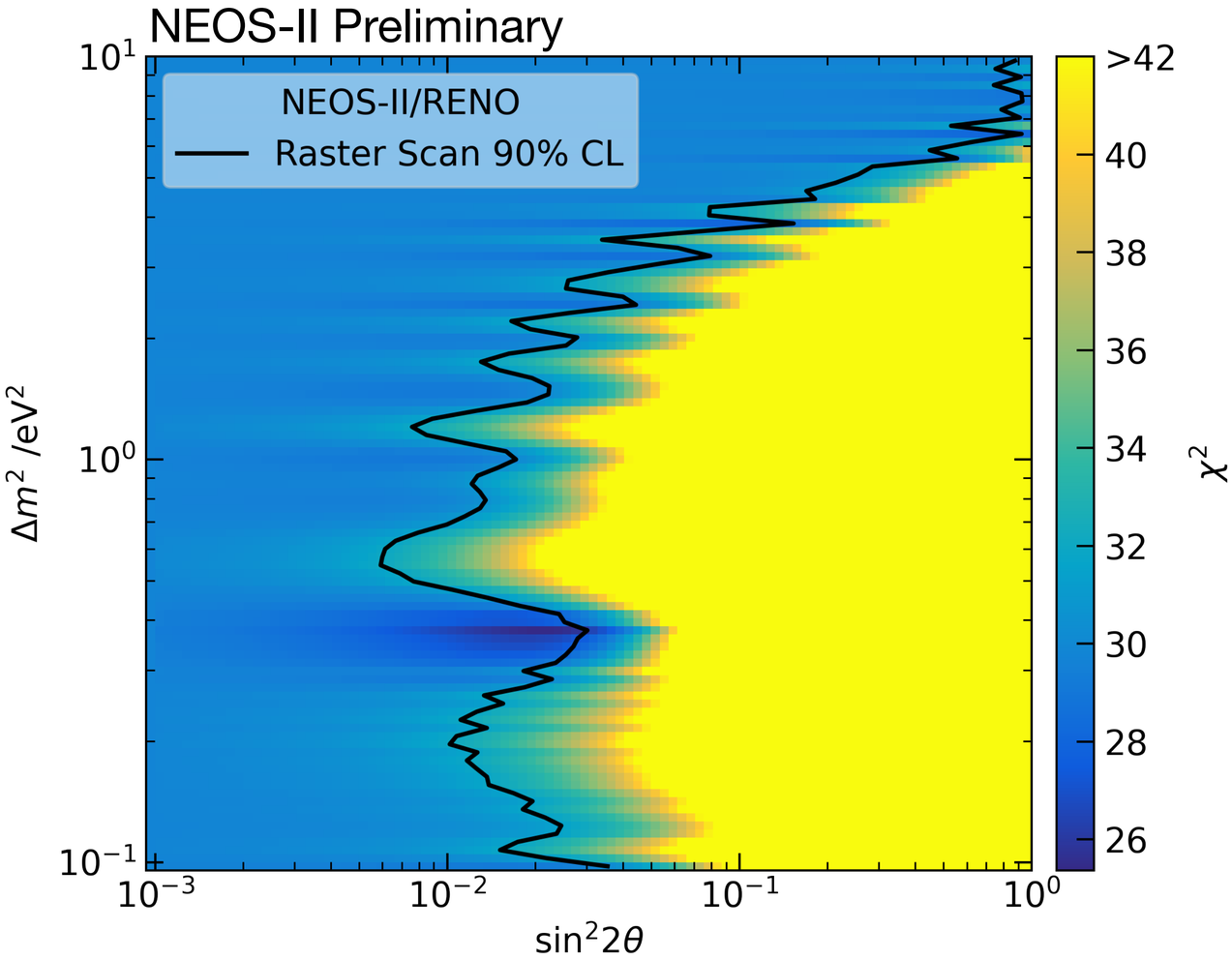
IBD spectrum decomposition



- Large statistical fluctuations in the ^{239}Pu spectrum.
- Inconclusive for a sole isotope responsible for the bump.

SBL oscillation: negative result

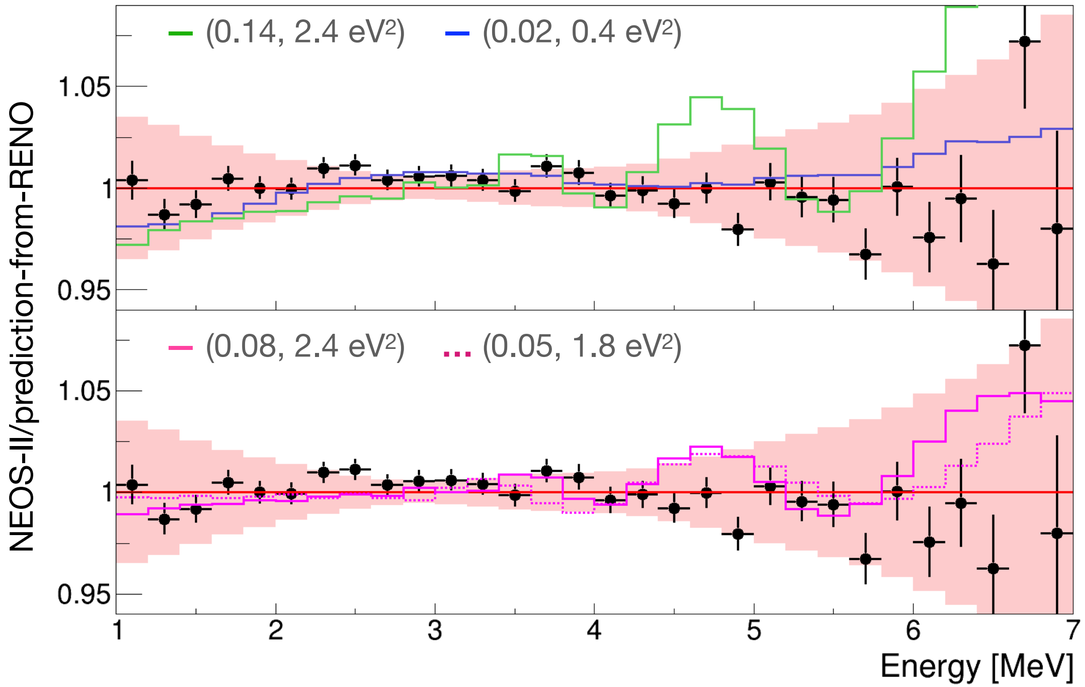


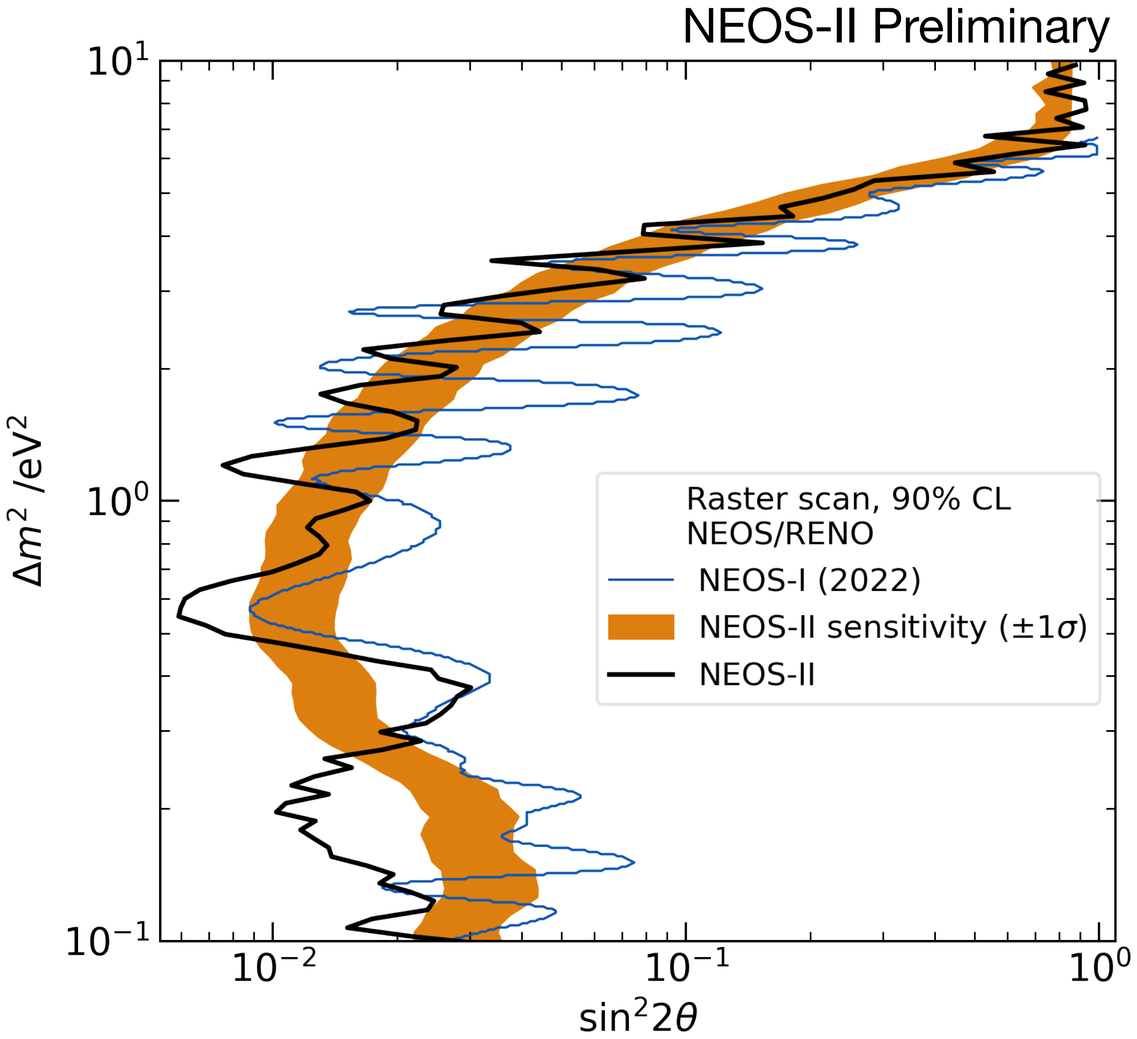


- Best fit at ($\sin^2 2\theta$, Δm^2) = (0.02, 0.4 eV^2),
  - $\Delta\chi^2 = \chi^2_{3\nu} - \chi^2_{4\nu}$ = 29.7-25.4 = 4.3

Comparison with NEOS-I result

($\sin^2 2\theta$, Δm^2 /eV^2)	χ^2	Note
x	29.7	3v
(0.02, 0.4)	25.4	Best fit (this work)
(0.08, 2.4)	44.7	NEOS-I/RENO 1st best
(0.05, 1.8)	46.1	NEOS-I/RENO 2nd best
(0.14, 2.4)	77.1	RAA best





Summary

Results are being finalized

- Measured IBD yield: -2.7$_{\pm 2.5\%}$ of Huber-Mueller-Vogel prediction.
- (y_{235}, y_{239}) = (6.32$_{\pm 0.17}$, 4.70$_{\pm 0.28}$) $\times 10^{-43}$ cm^2/fission, y_{235}/y_{239}=1.37$_{\pm 0.08}$.
- No evidence for the short baseline oscillation from the 3+1ν model.