



Status of NEOS-II

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On behalf of the NEOS collaboration

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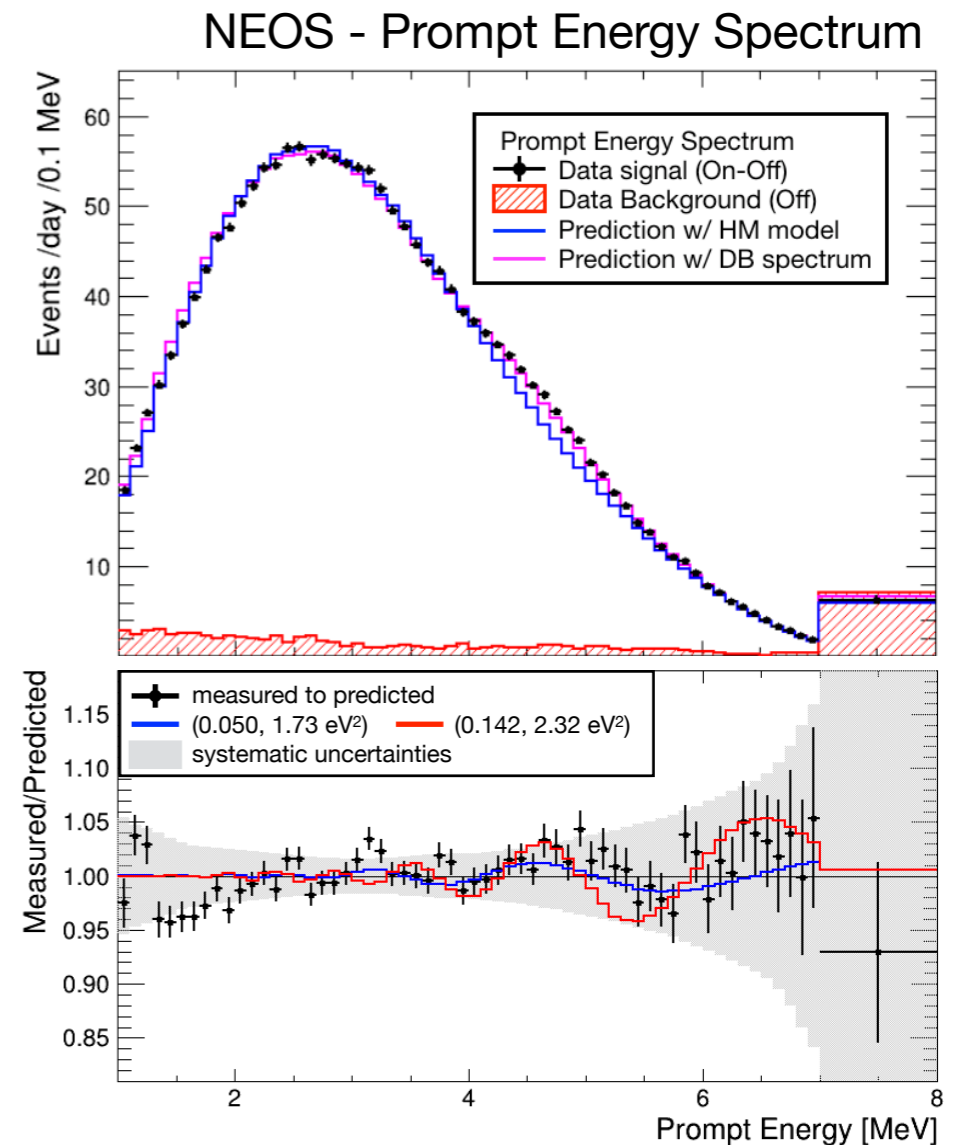
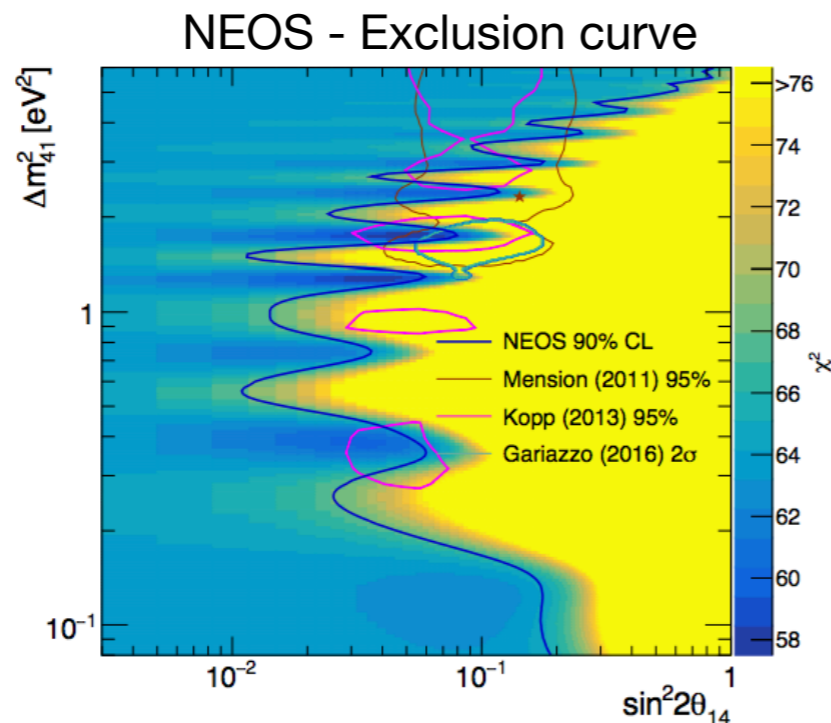
NEOS Experiment

- NEOS: **N**eutrino **E**xperiment for **O**scillation at **S**hort baseline
- NEOS collaboration
 - 20 collaborators at 7 institutes



NEOS-phase1

- Reactor antineutrino anomaly¹⁾
 - **Deficits** in measured antineutrino fluxes
 - Confirmed in other recent experiments
- NEOS-I
 - Data taking: Jul. 2015 ~ May 2016
(ON ~180 day & OFF ~45 days)
 - To test the hypothesis for the (3+1) ν framework
 - **No strong evidence** of light sterile- ν^2 .

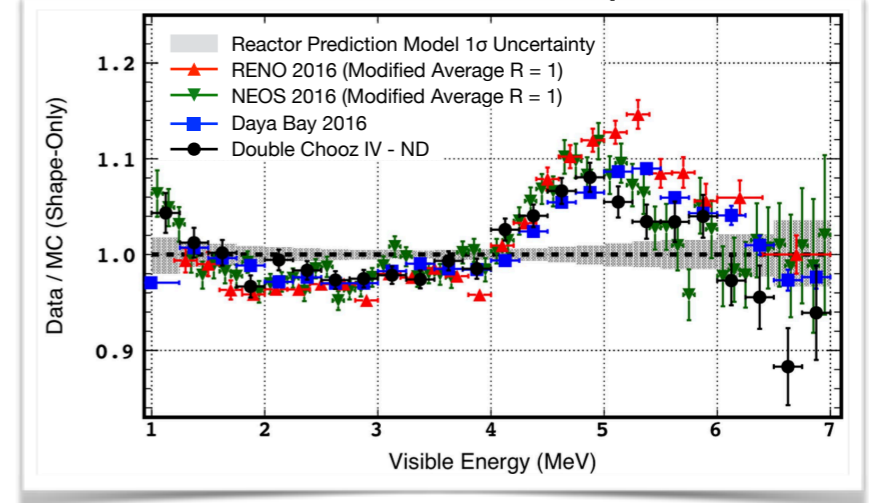


1) Phys. Rev. D **83**, 073006 (2011)
2) Phys. Rev. Lett. **118**, 121802 (2017)

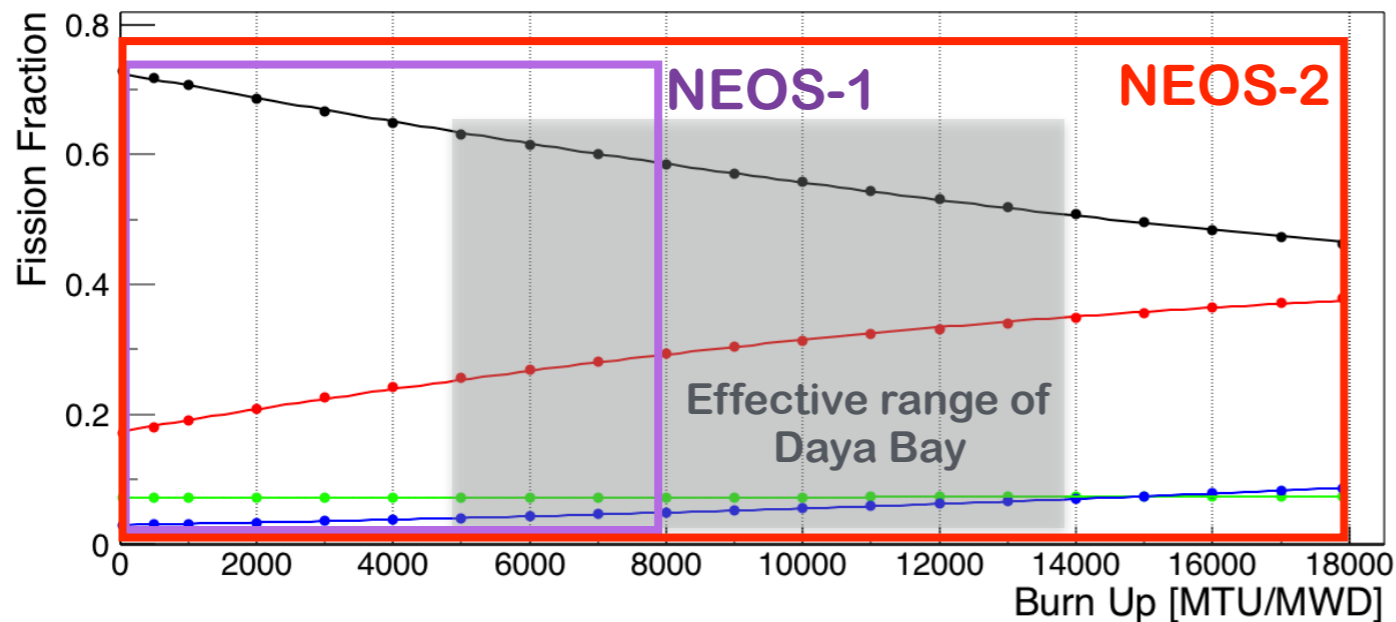
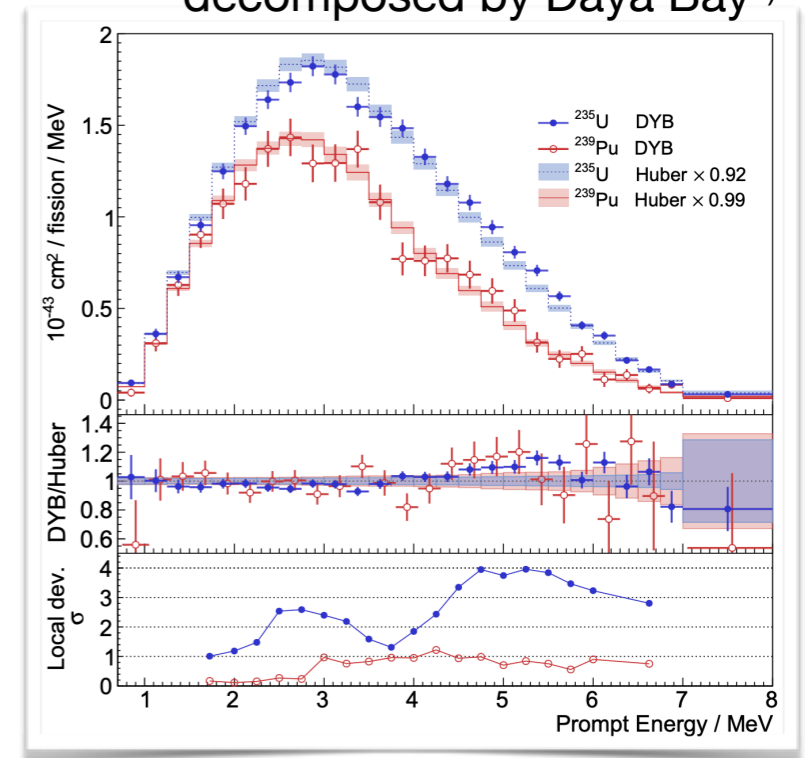
NEOS-phase2

- 5-MeV excess
 - Recent experiments have observed the excess.
 - Is ^{235}U the source of the excess?
- NEOS-II
 - To understand the reactor neutrino spectrum
 - Rate+shape analysis for sterile- ν search
 - Similar uncertainty to Daya Bay is expected thanks to **larger changes in fission fraction**.

5-MeV excess in recent experiments³⁾



^{235}U & ^{239}Pu spectra decomposed by Daya Bay⁴⁾

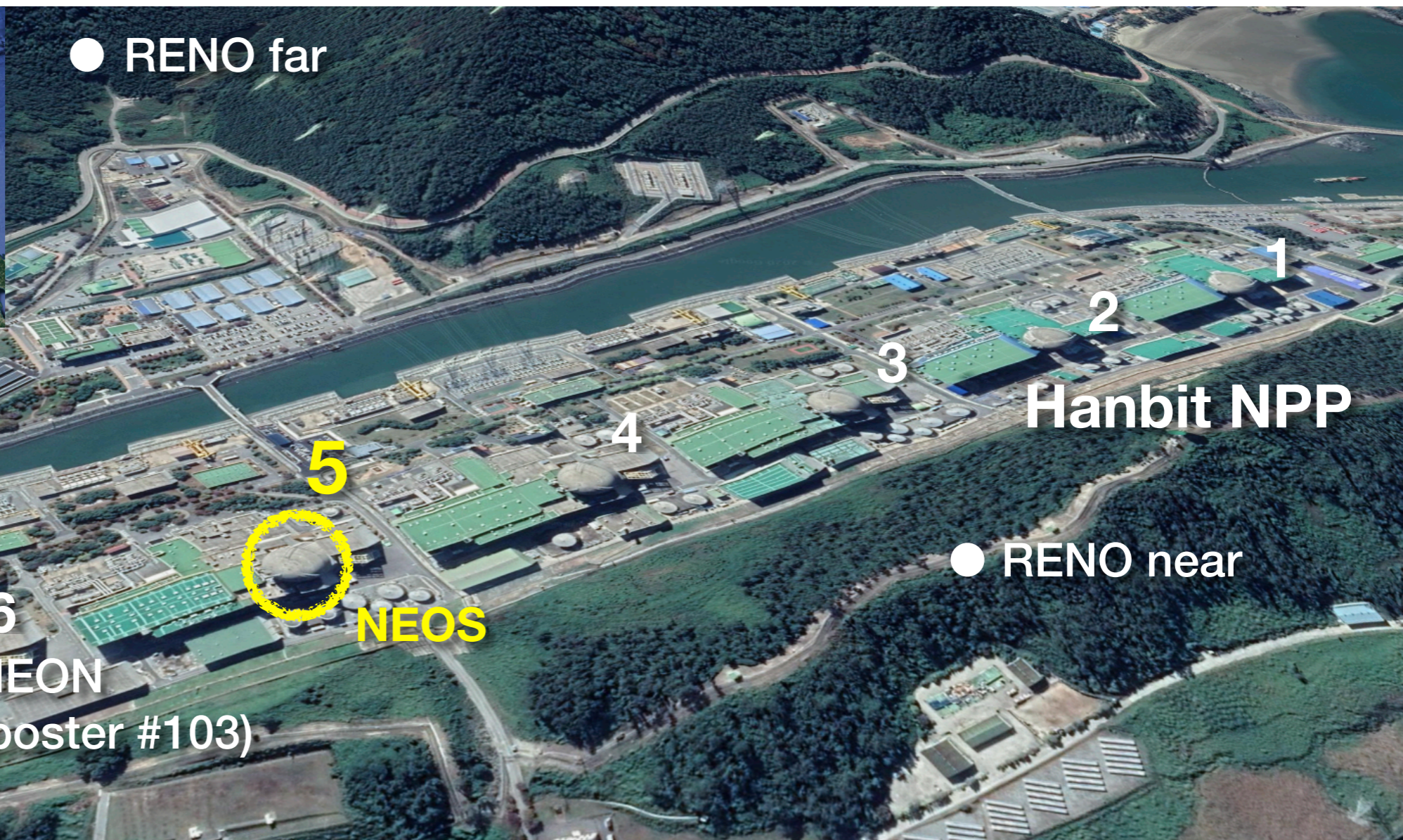


3) Nature Physics **16**, 558-564 (2020)

4) Phys. Rev. Lett. **118**, 251801 (2017)

Experimental Site

- Hanbit-5 reactor in Yeonggwang, Korea
- 2.8-GW_{th} commercial reactor
- Core size: 3.1-m diameter and 3.8-m height



NEON (Neutrino Elastic-scattering Observation with Na(Tl) Experiment)
 Institute for Basic Science (IBS) / Department of Physics and Astronomy, Seoul National University
 On behalf of the NEON collaboration

Abstract
 NEON (Neutrino Elastic-scattering Observation with Na(Tl) Experiment) aims at observation of a coherent elastic neutrino-nucleus scattering (CENS) using reactor electron antineutrino with Na(Tl) crystal detectors at Hanbit nuclear power plant in Yeonggwang, South Korea. The NEON detector consists of a 15 kg Na(Tl) crystal from which will be installed 24 meters from the reactor core. Currently, the detector was installed for studies of basic science measurements (CENS) together with a recently received 100-ton lead and 20-ton copper calorimeter, and 30 cm high density polyethylene. We are testing data stability and studying the Na(Tl) crystal background and threshold. We are planning to install the detector in the reactor and run the experiment in this fall.

Introduction
 • To observe coherent elastic neutrino-nucleus scattering for reactor neutrinos
 • Study new physics
 • Measure neutrino magnetic moment
 • Neutrino non-standard interaction
 • Reactor monitoring
 • Neutrino-electron scattering

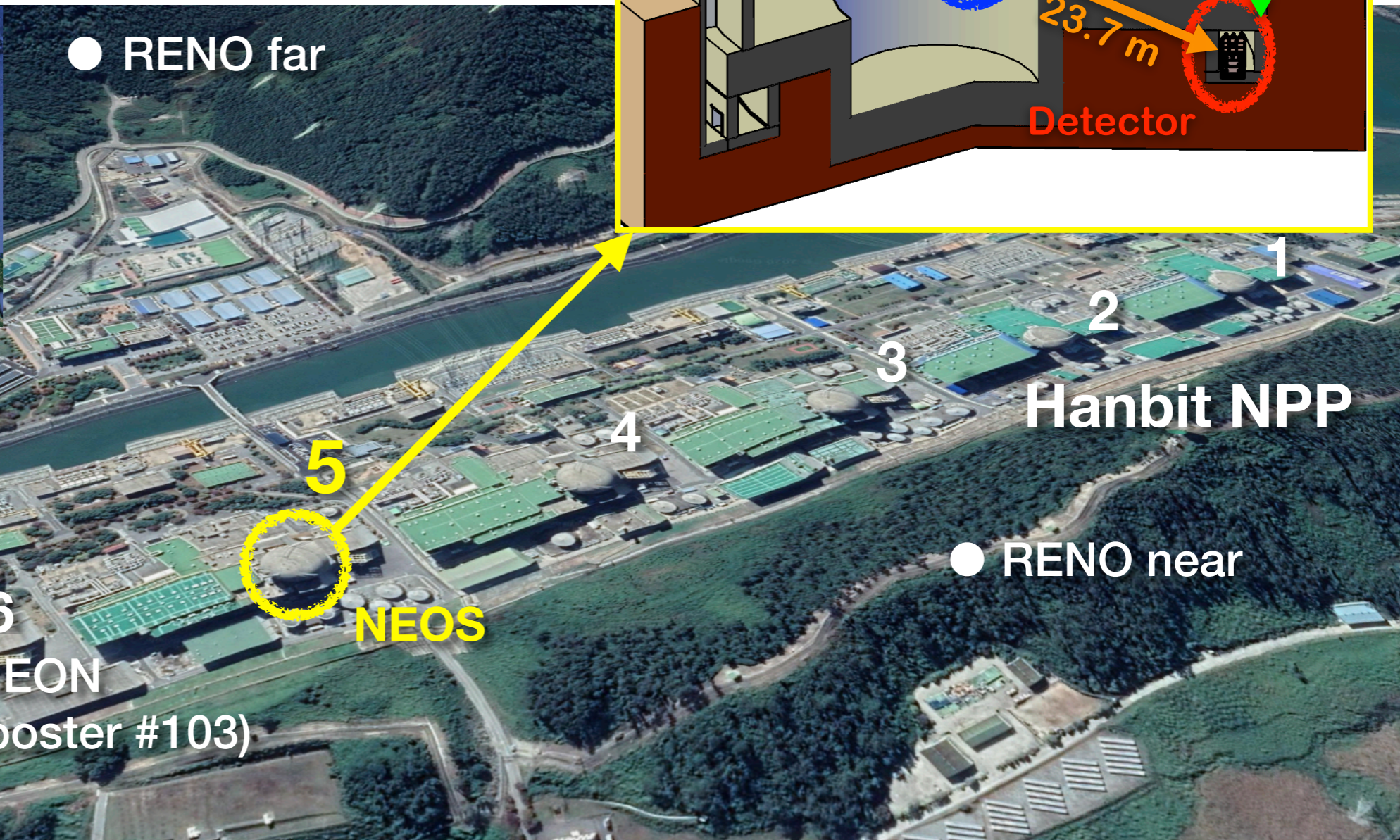
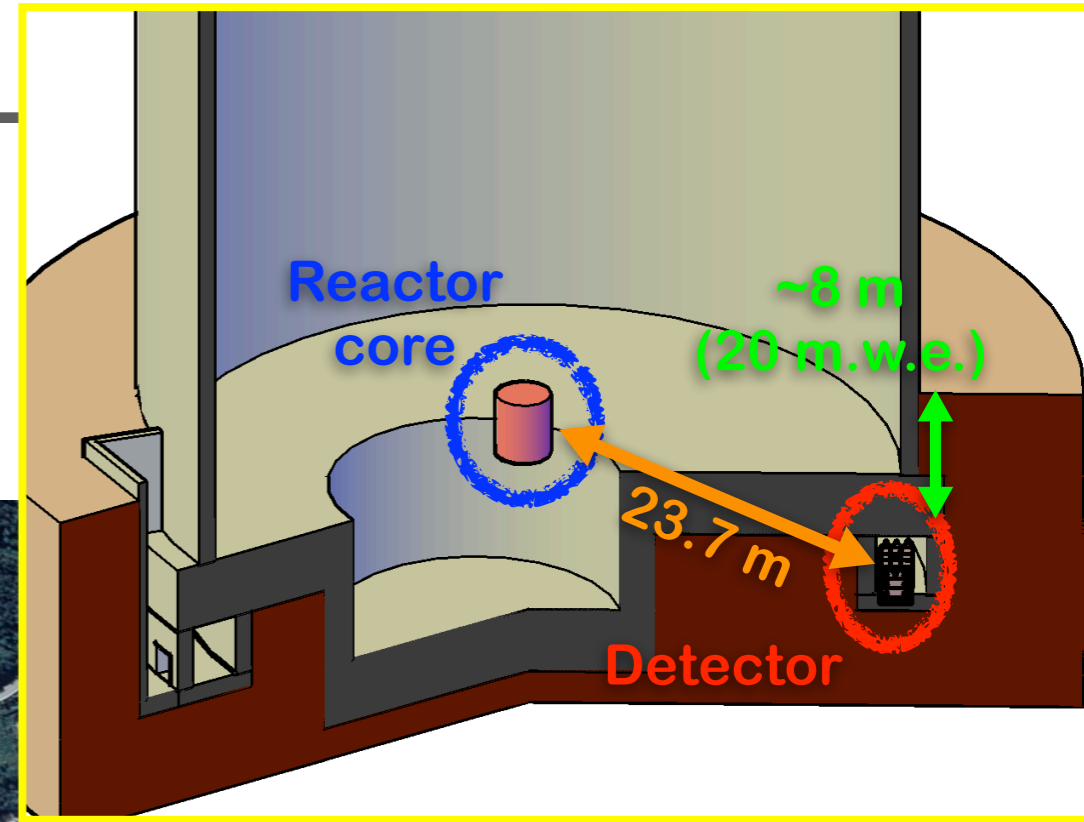
Experiment
 • Experiment site: Reactor Unit 5 (RNU-5) of Hanbit Nuclear Power Plant in Yeonggwang, South Korea
 • Reactor power: 2.8 GW_{th}
 • Distance from the reactor core: 23.7 m
 • Detector: 15 kg Na(Tl)
 • Expected Neutrino Flux at experiment site: $7.1 \times 10^{17} \text{ cm}^{-2} \text{ s}^{-1}$

NEON Detector R&D and Background Study
 • A Na(Tl) crystal should be encapsulated to block moisture
 • Encapsulation design
 • We developed new encapsulation design to reduce leak risk
 • Attached the crystal diameter gap to the PMT cap
 • Minimized material between the crystal and the PMT
 • We took care of the crystal surface treatment
 • We took care of the crystal surface treatment
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NEOS (poster #103)
 • Array of the Na(Tl) detector (total 15 kg)
 • 1st floor: three crystals (dimension: 3" x 4" x 4", mass: 3.38 kg)
 • 2nd floor: three crystals (dimension: 4" x 4" x 4", mass: 1.68 kg)
 • Shading material
 • 2000-level scintillator (lapping multiple events with ten 5" PMTD)
 • 10 cm lead, 2.5 cm borated PE, 30 cm HDPE
 • The data acquisition (DAQ) system is similar to the COSINE-100 experiment DAQ
 • The run has begun at IBS Laboratory
 • Simulation study is ongoing

Experimental Site

- Detector in tendon gallery
 - 23.7-m baseline and 20-m.w.e. overburden
 - Muon rate: $\sim 1/6$ of the ground ($\sim 28.7 \text{ Hz/m}^2$)



● RENO far

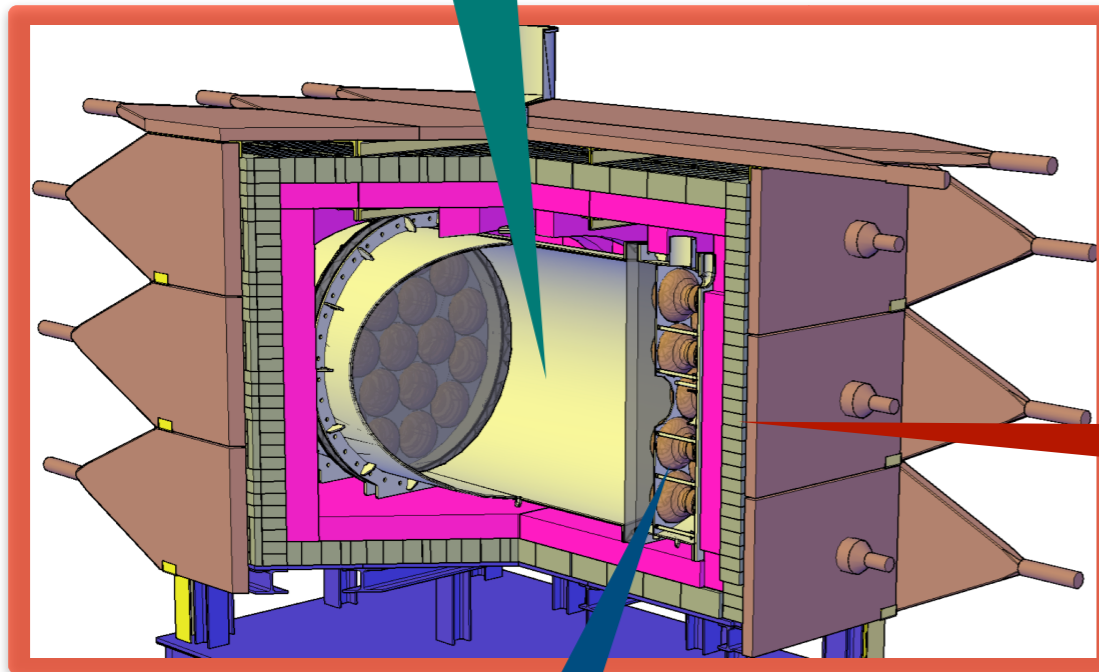
● RENO near

● NEON (poster #103)

NEOS Detector

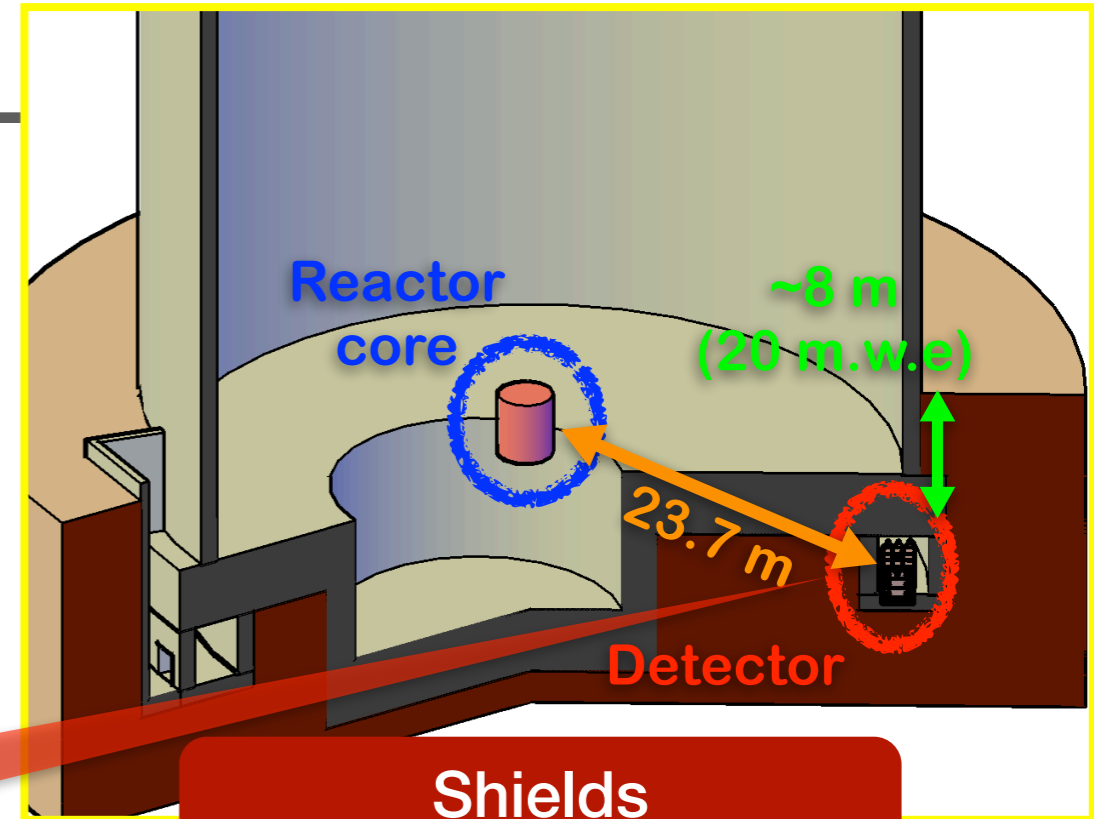
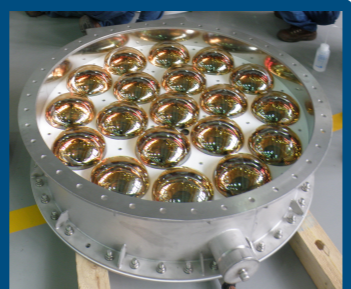
Active target

Homogeneous
1,008-L volume
0.48% Gd-LS
Mixed LS
(LAB + DIN)



Photomultiplier tubes

Two buffer tanks at both side of target
Acrylic window b/w target & buffers
19 R5912 (8 inch) PMTs in each buffer



Shields

10-cm thick B-PE (n^0) and Pb(γ)
Muon veto detectors
3-cm thick plastic scintillator
15 panels with PMTs
Except bottom side



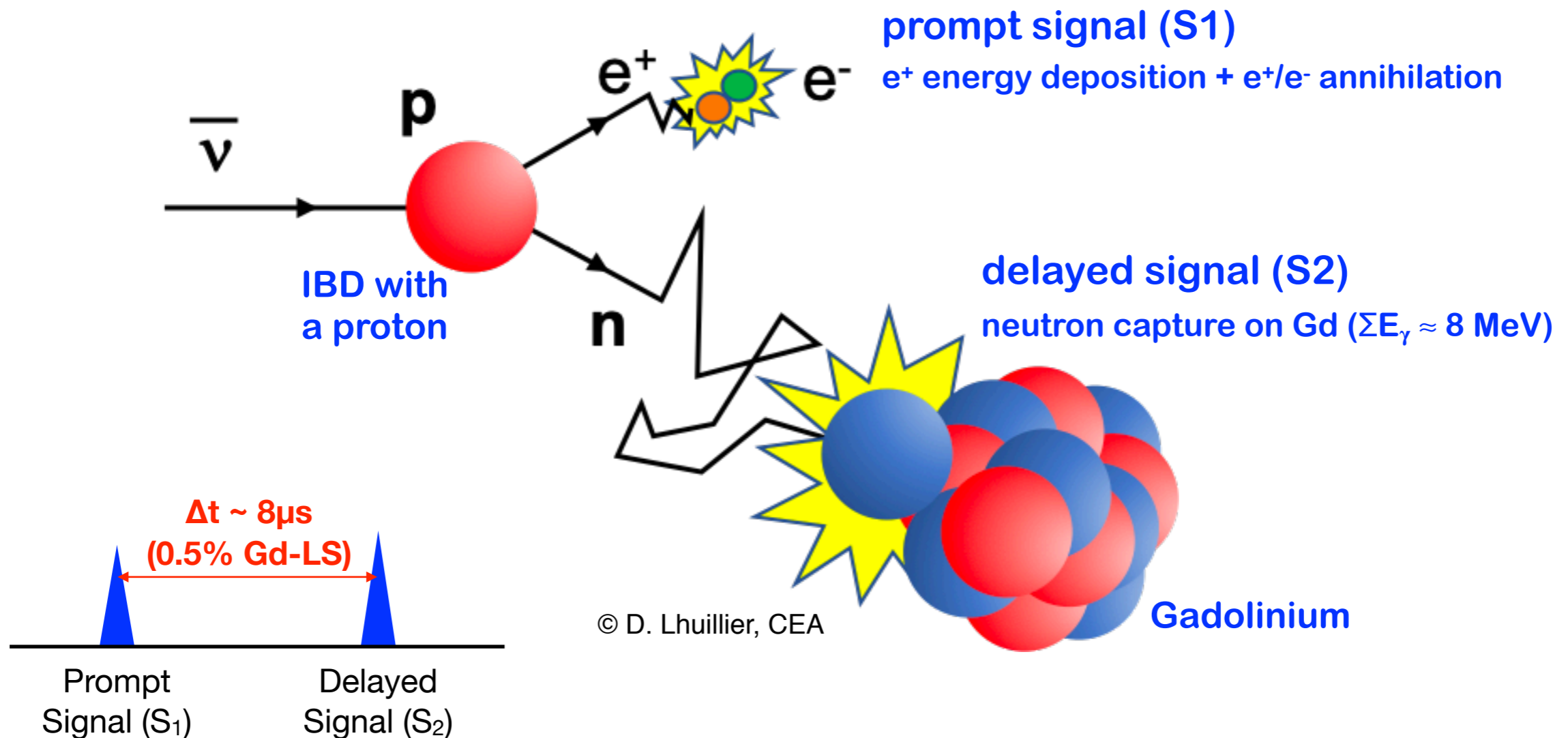
DAQ systems

500 MS/s Flash ADC for target
(recording waveforms for PSD)
62.5 MS/s ADC for muon counters



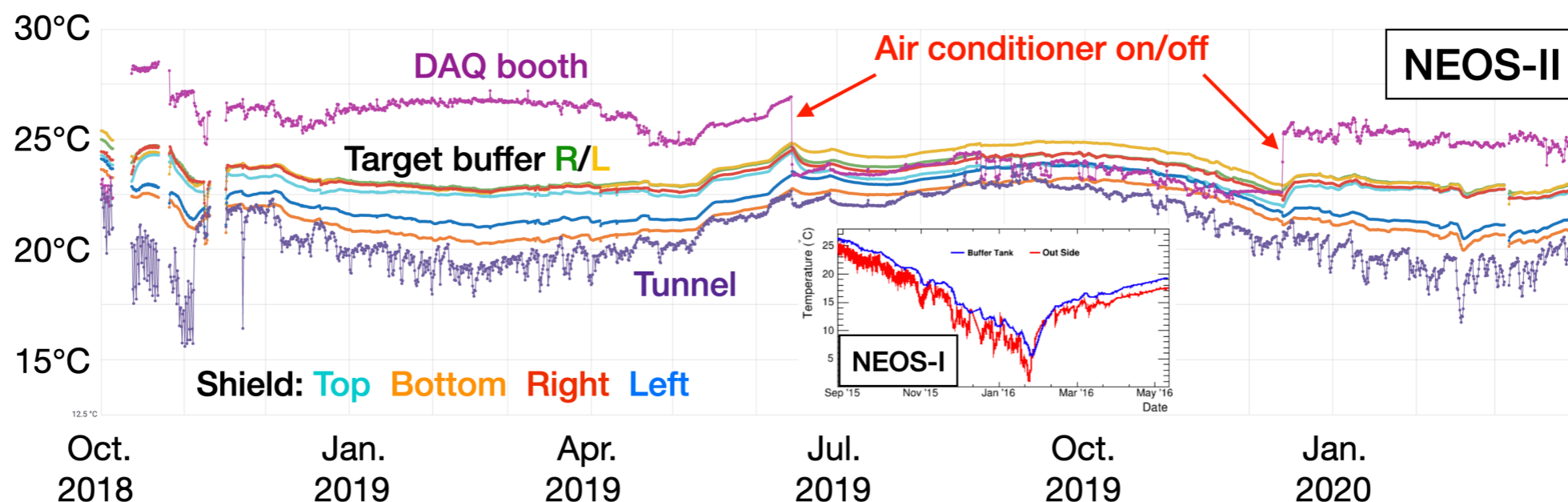
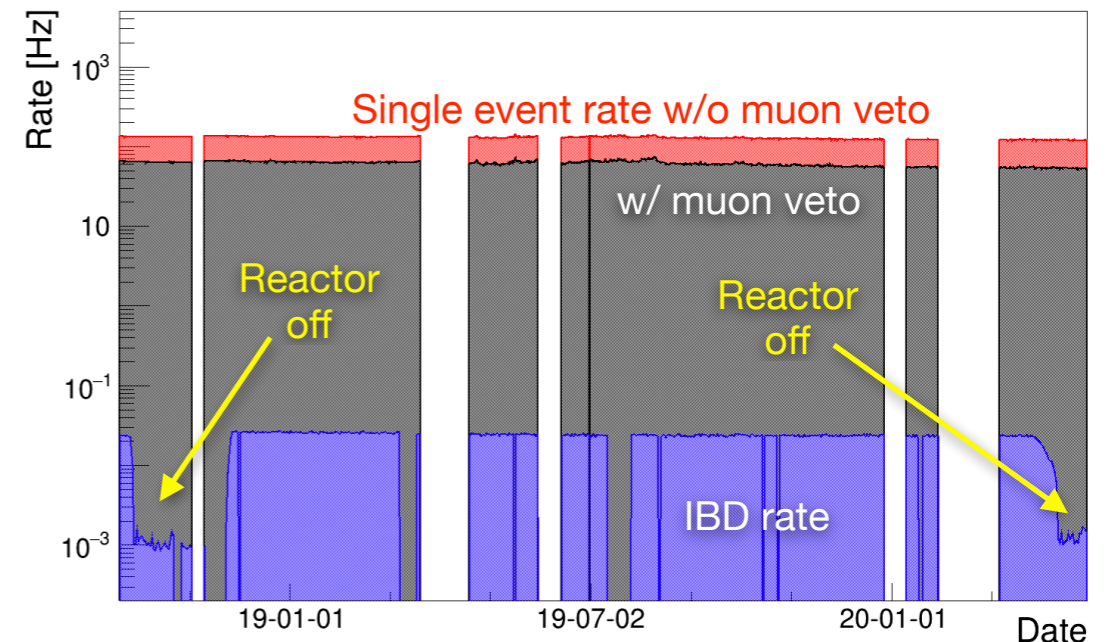
Inverse Beta Decay

- NEOS detector is a calorimeter with Gd-LS to detect the electron antineutrino.
 - Neutrino detection through **inverse β -decay (IBD)** in the active target



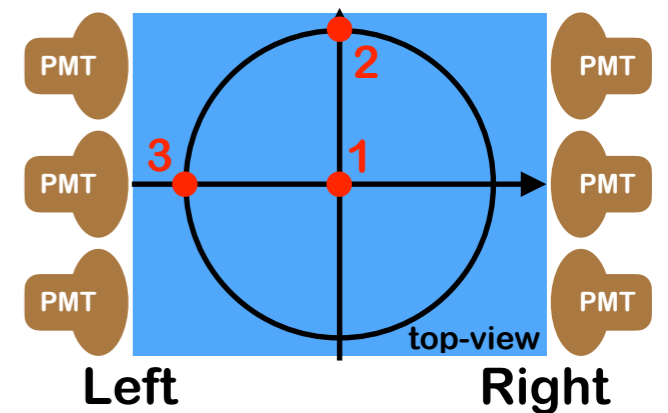
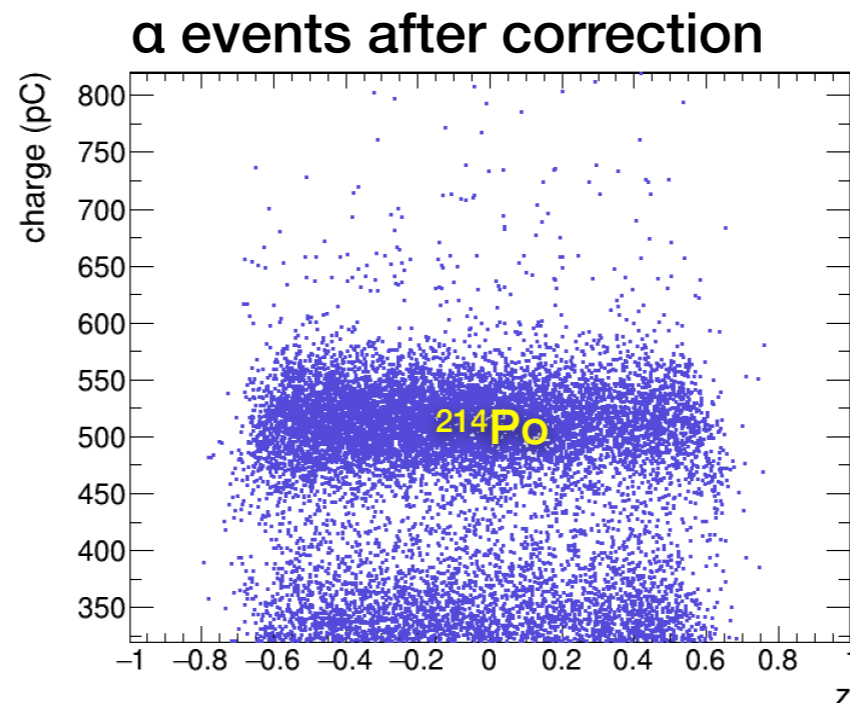
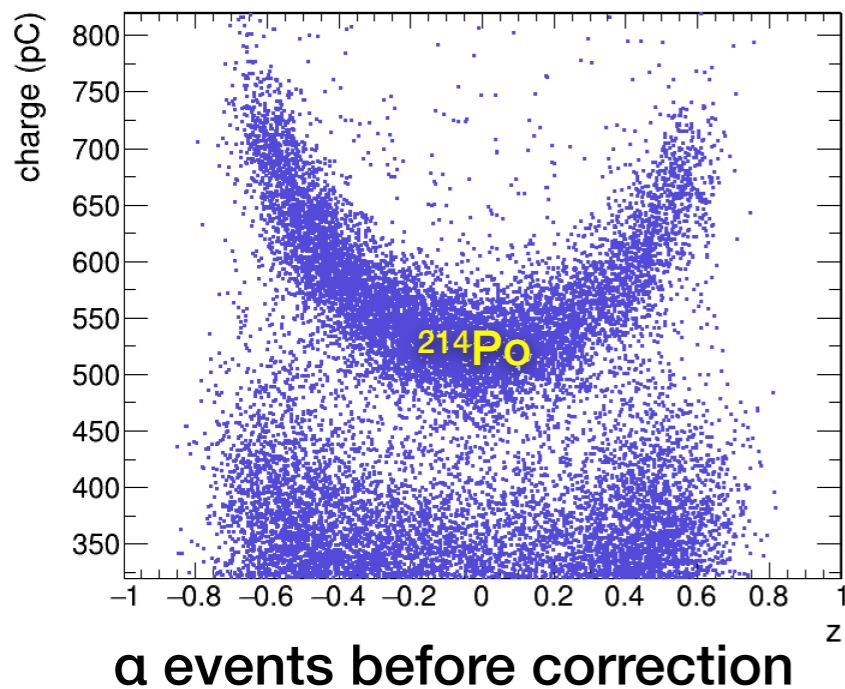
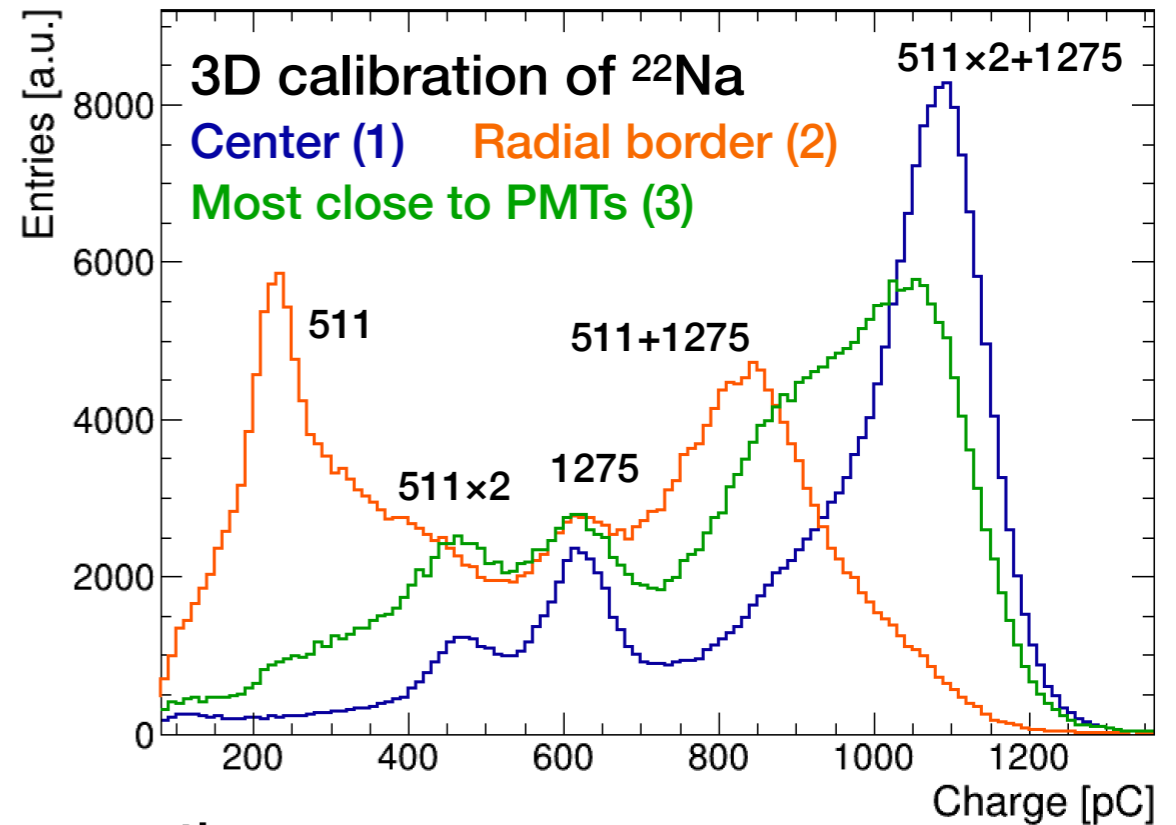
Detector Operation

- Installation in Sep. 2018
- Temperatures of target buffers within $\sim 2^\circ\text{C}$ ($\sim 20^\circ\text{C}$ in NEOS-I)
 - Air conditioner in the booth
- Data taking began in the same month.
 - The number of IBD candidates is similar to phase1.
 - $\sim 90\%$ DAQ efficiency
 - Data taking will be over in Sep. 2020.



Detector Response

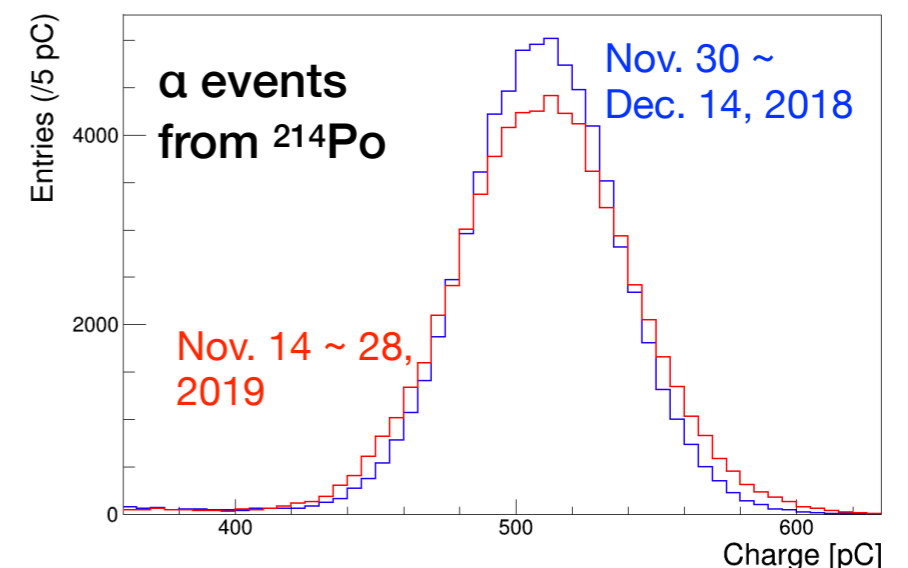
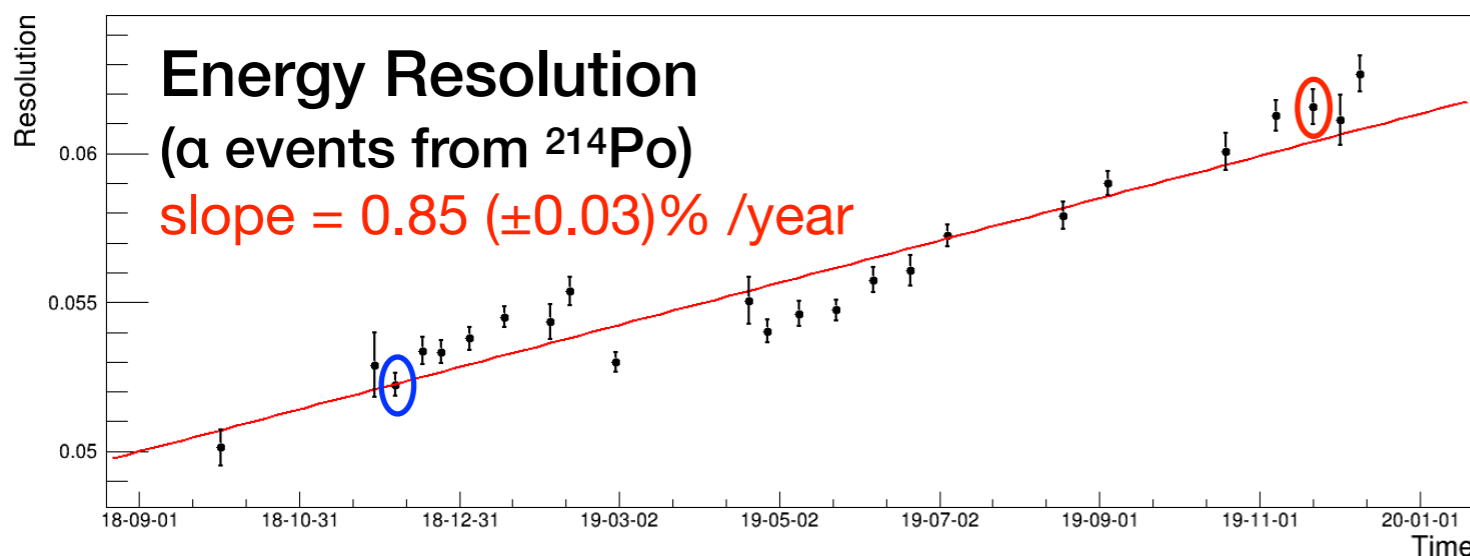
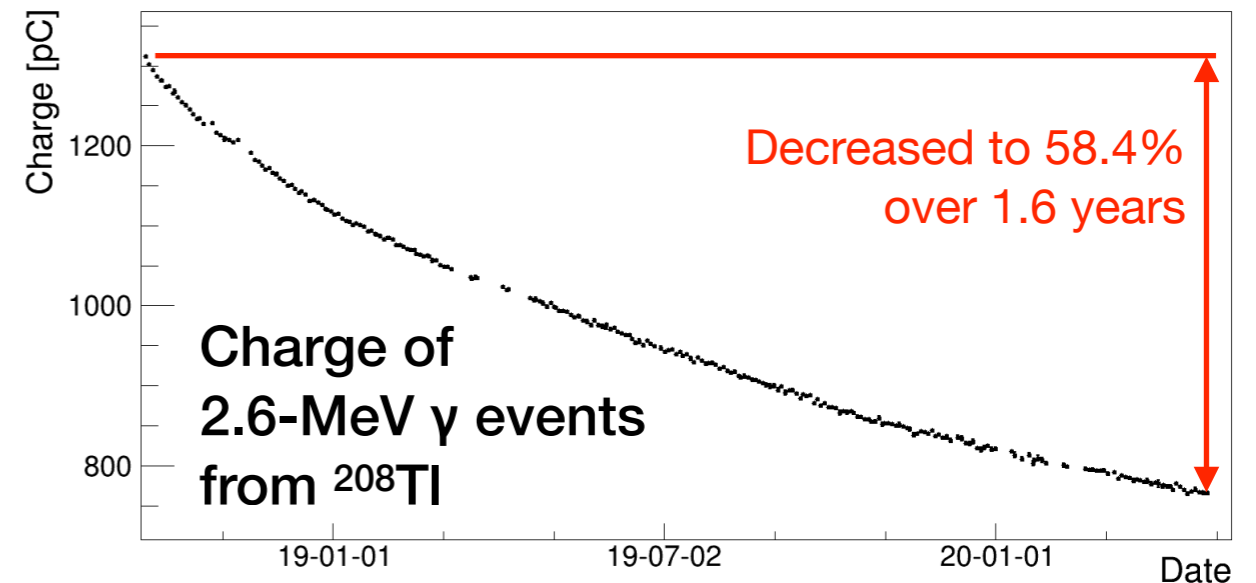
- Escaping γ events
 - It can **distort energy distribution** of γ events.
 - Prompt signal includes **two 0.511-MeV γ s**.
- Non-uniformity
 - Detector response **depends on position**.
 - Non-uniformity is corrected with α events.



$$z = \frac{Q_{\text{right}} - Q_{\text{left}}}{Q_{\text{right}} + Q_{\text{left}}}$$

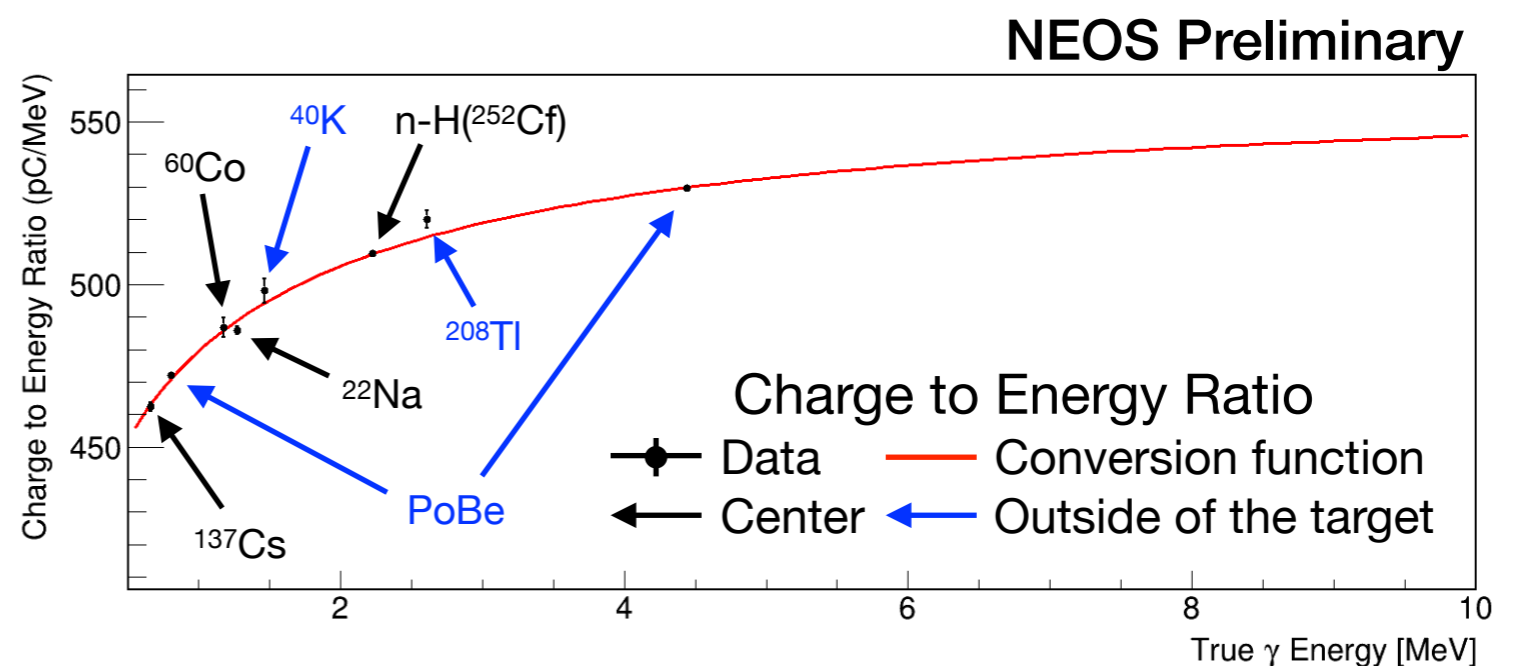
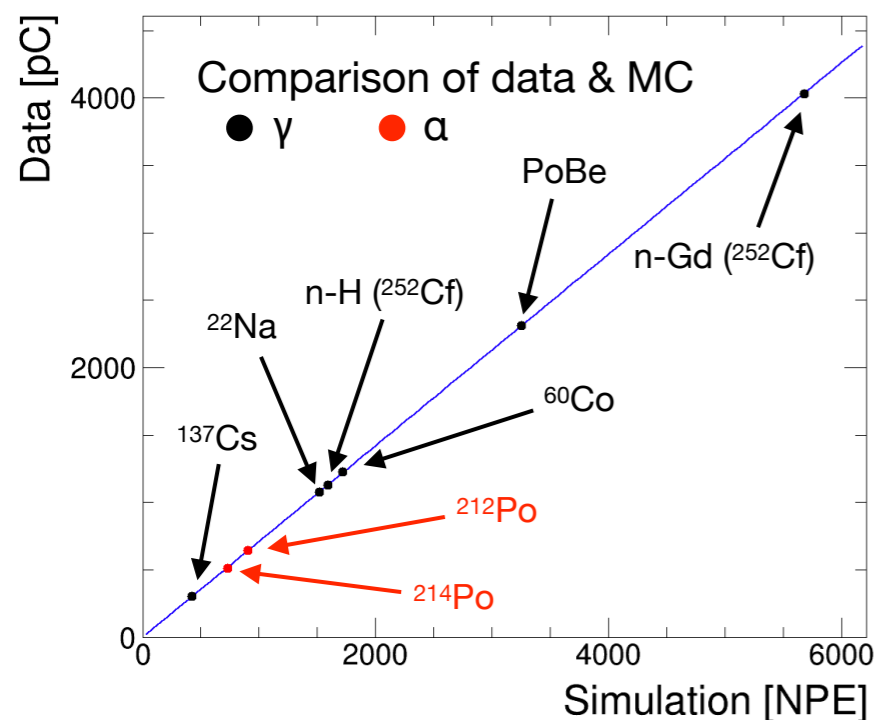
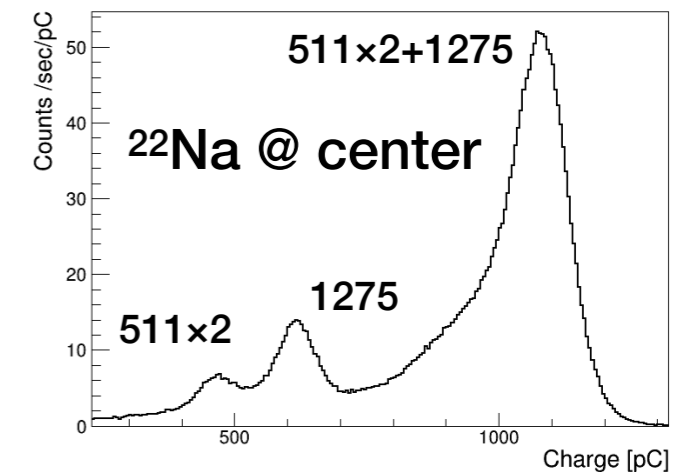
An Issue Regarding Light Yield

- Decreasing light output
 - Precipitation in a stored LS sample
 - Decreased to $\sim 60\%$ over 1.6 years
- Increasing energy resolution
 - Increased to 7% from 5% @ 1 MeV
- Effect on spectra decomposition by resolution change
 - We cannot see any significant differences due to the resolution change.
 - More details in Poster #433



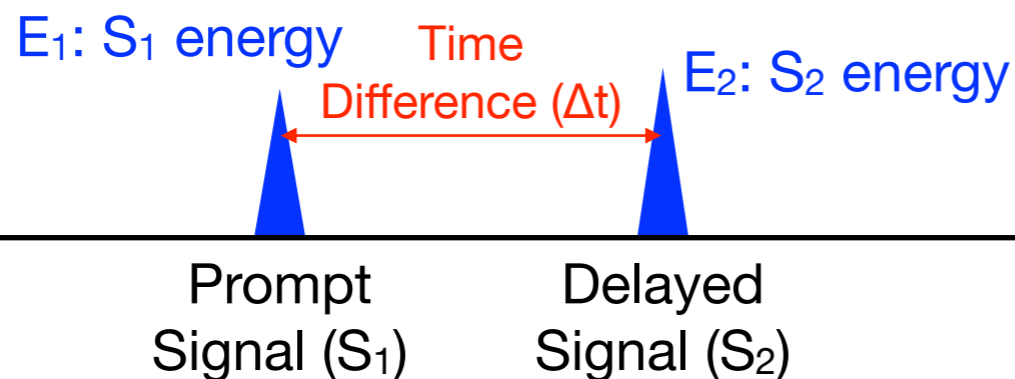
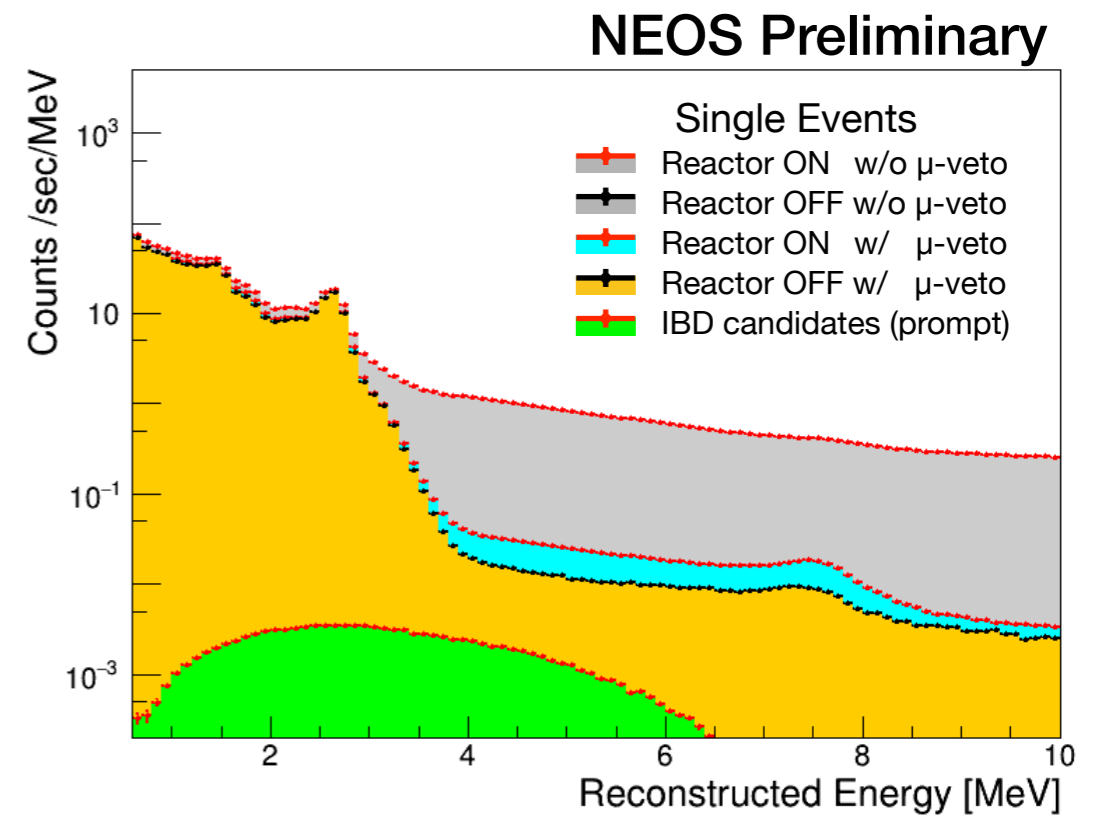
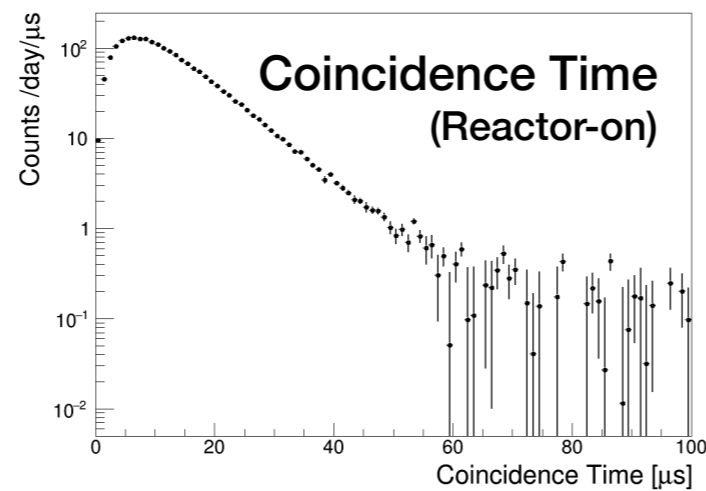
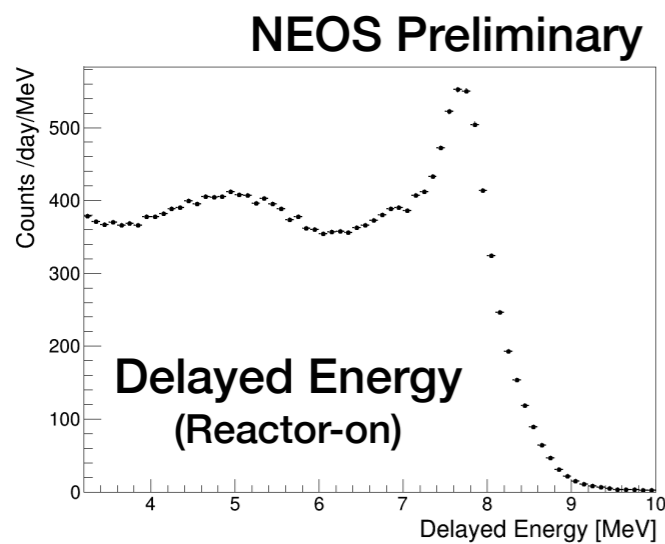
Energy Calibration

- Calibration sources
 - Point sources: ^{137}Cs , ^{60}Co , ^{22}Na , PoBe and ^{252}Cf (biweekly)
 - Volume sources: ^{40}K (PMT glass), ^{208}Tl (B-PE) and α/β events (LS)
 - Used for position/time dependent corrections as well as energy calibration.
- Charge to energy conversion
 - Only **single γ** sources
 - Non-linearity due to quenching and Cherenkov effects.
 - **Simulation describes the data well.**



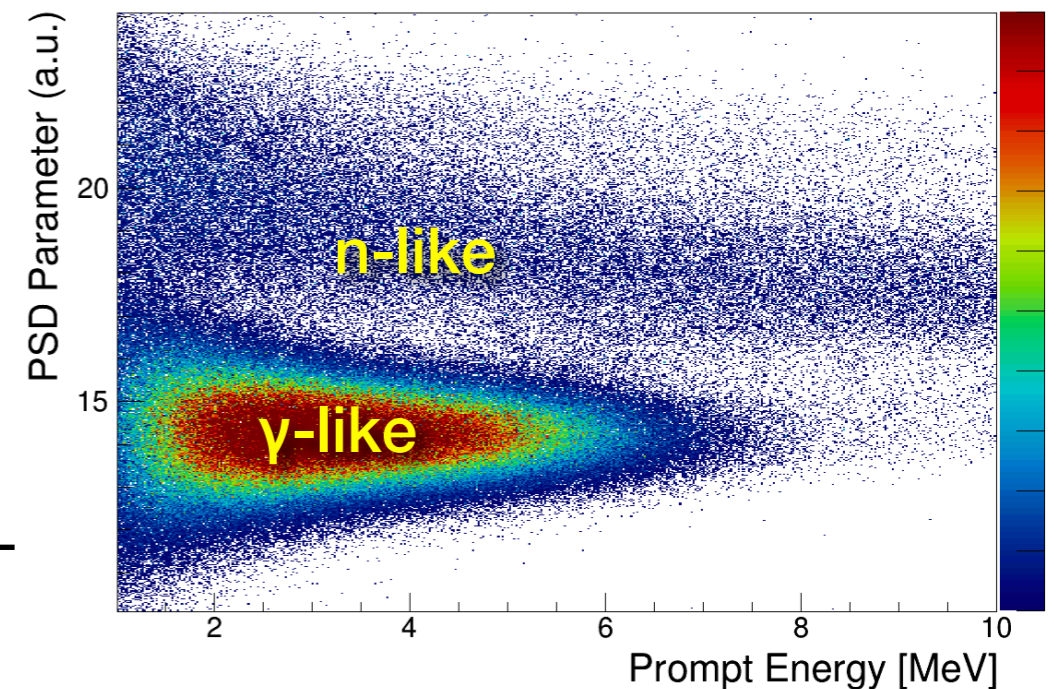
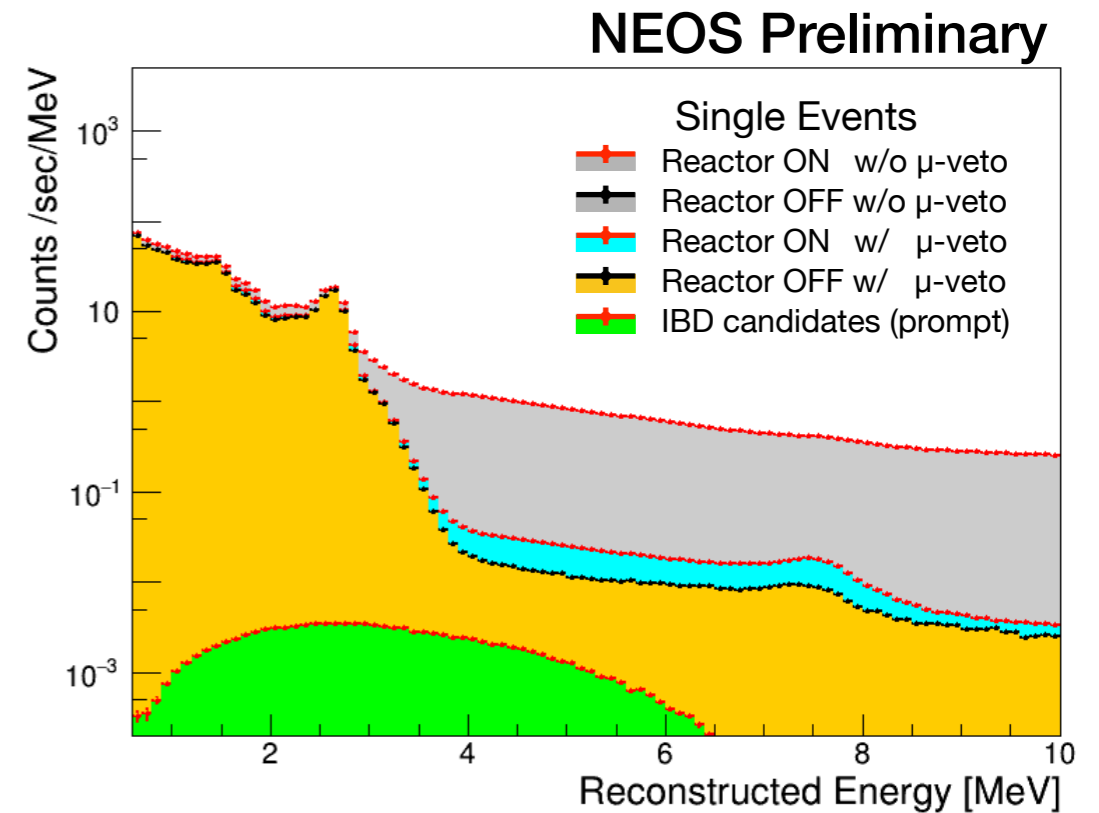
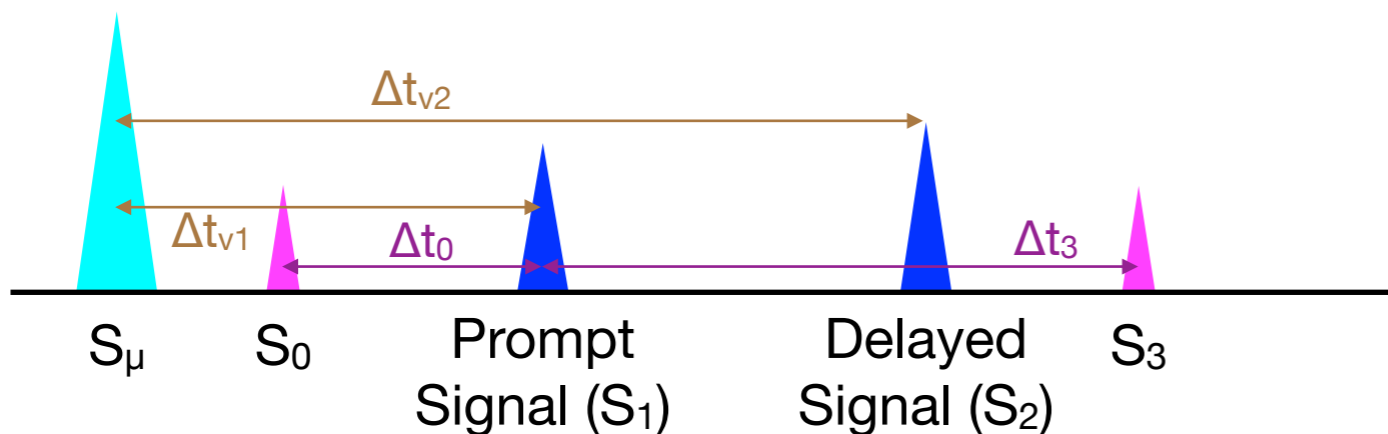
IBD Selection

- Criteria for single event
 - Energy cut, electronic noise and flasher events removal
- Criteria for IBD selection
 - Energy range and time difference



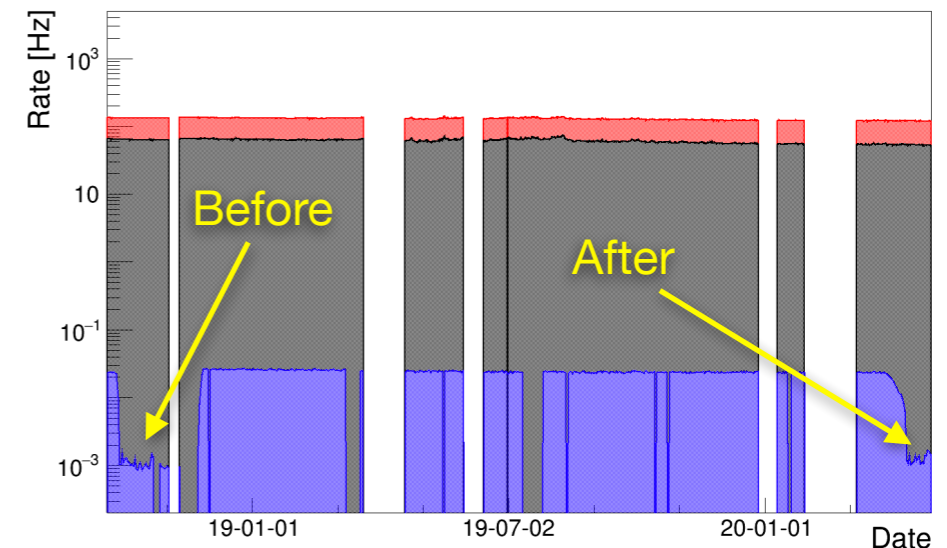
IBD Selection

- Criteria for single event
 - Energy cut, electronic noise and flasher events removal
- Criteria for IBD selection
 - Energy range and time difference
- Criteria for background rejection
 - Muon veto: Δt_{v1} & Δt_{v2}
 - Multiplicity: Δt_0 & Δt_3
 - Pulse shape discrimination (PSD)
- More details in Poster #299

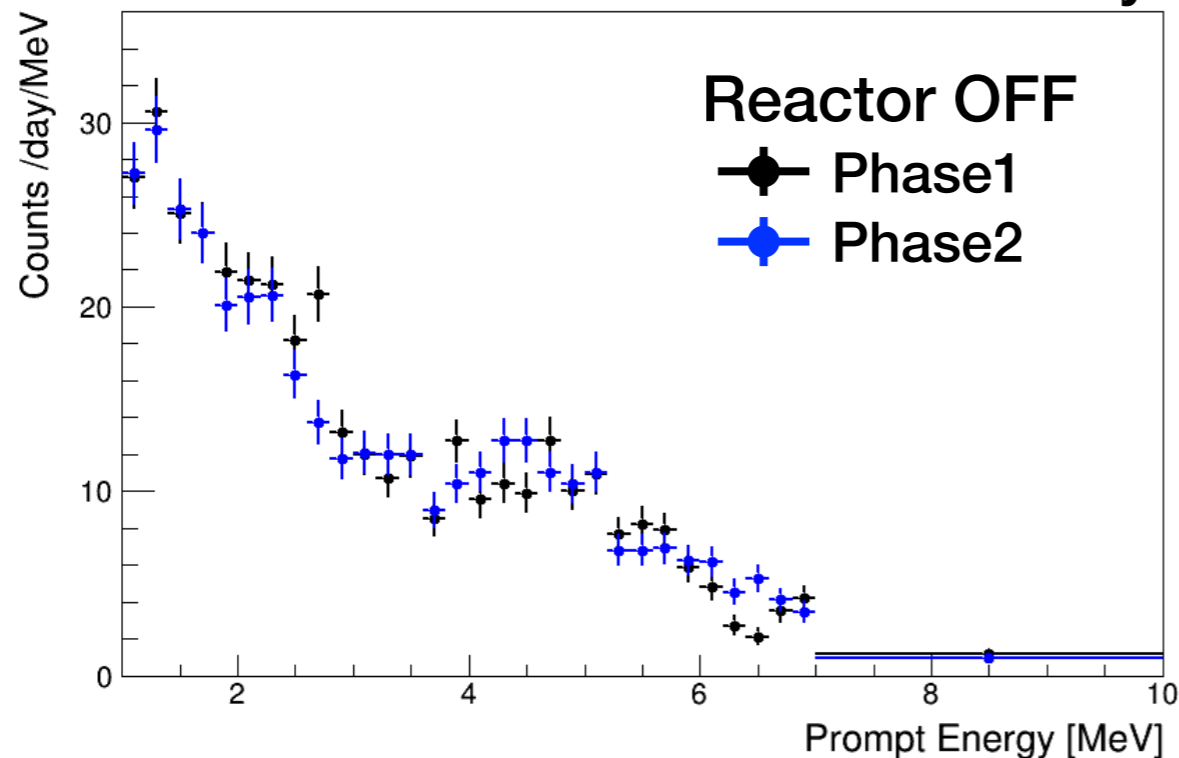


Comparison of Background

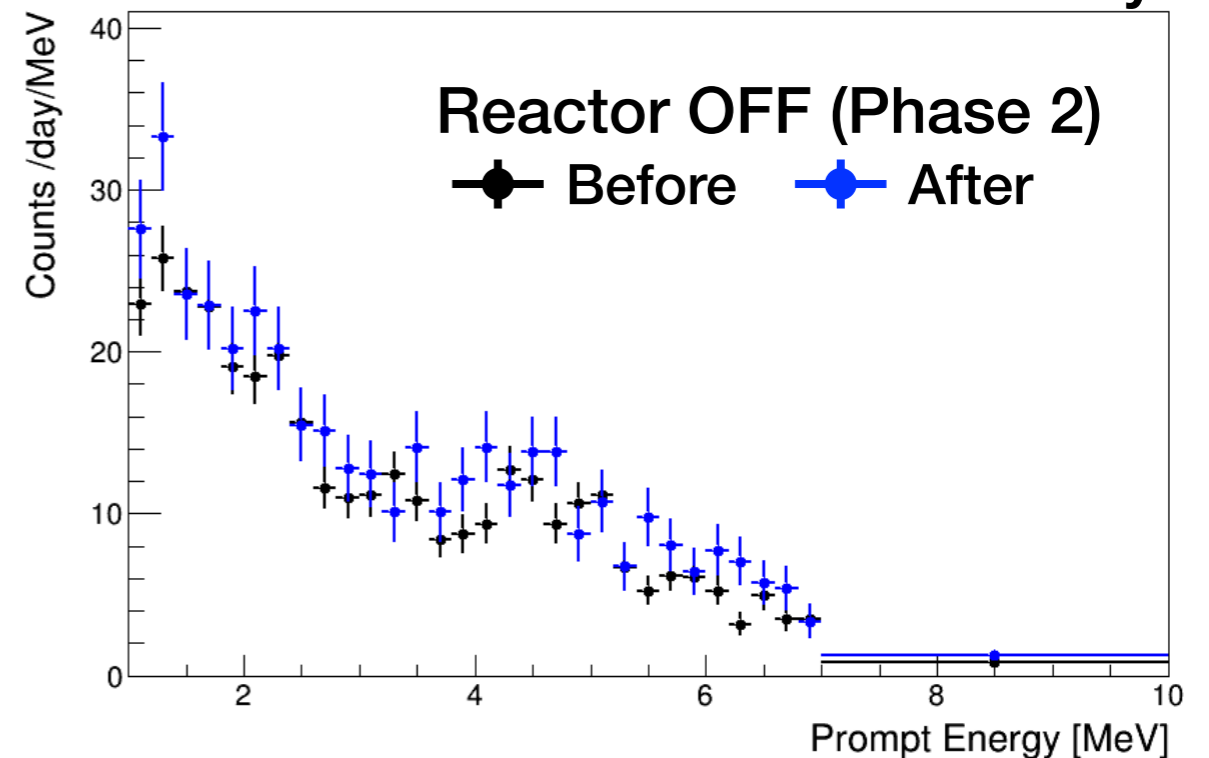
- Phase1 vs. Phase2
 - **Similar** rate and shape
 - Energy scale and IBD criteria can be updated.
- Before vs. after reactor-on period
 - No significant changes.
 - Background is **stable**.



NEOS Preliminary



NEOS Preliminary



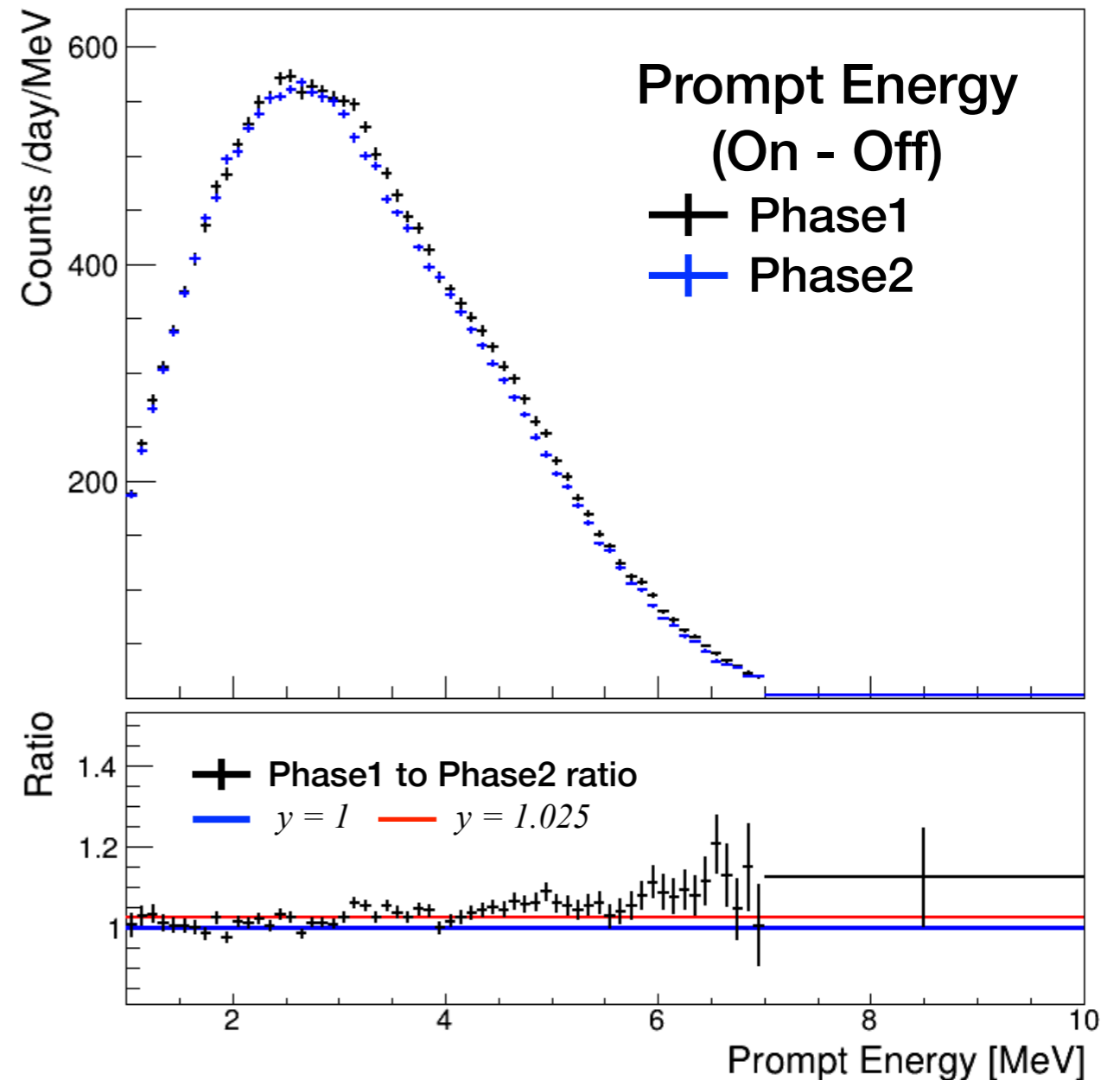
Phase1 VS Phase2

- Generally in an agreement
 - Rate: ~2.5% smaller than Phase1
 - Shape: slightly increasing in ratio
- Data will be compared with models after tuning MC.

NEOS Preliminary

	S/B ratio	# of IBD (off) [day]
Phase1	22.2	1977 (85)
Phase2	22.3	1925 (82)

NEOS Preliminary



Summary

- NEOS-II
 - Started from Sep. 2018 with the same design and site as NEOS-I
 - Data was taken in a full cycle, and the experiment will be ended when a new cycle begins (~Sep. 2020).
- Stability issue
 - The initial performance was similar to phase1, but charge has been dropping due to the LS issue.
 - No serious effect on spectra decomposition due to the resolution changes
- Analysis status & Plan
 - Background stability is confirmed.
 - Prompt spectrum of phase2 agrees with that of phase1.
 - MC tuning is almost done, so we expect to show the comparison with model soon.
 - Study for spectra decomposition is ongoing.
 - Rate+shape analysis for sterile- ν is also in progress.

**Thank You
for Your Attention !!!**