Status of NEOS-II

Young Ju Ko

Center for Underground Physics at Institute for Basic Science (IBS)

On behalf of the NEOS collaboration

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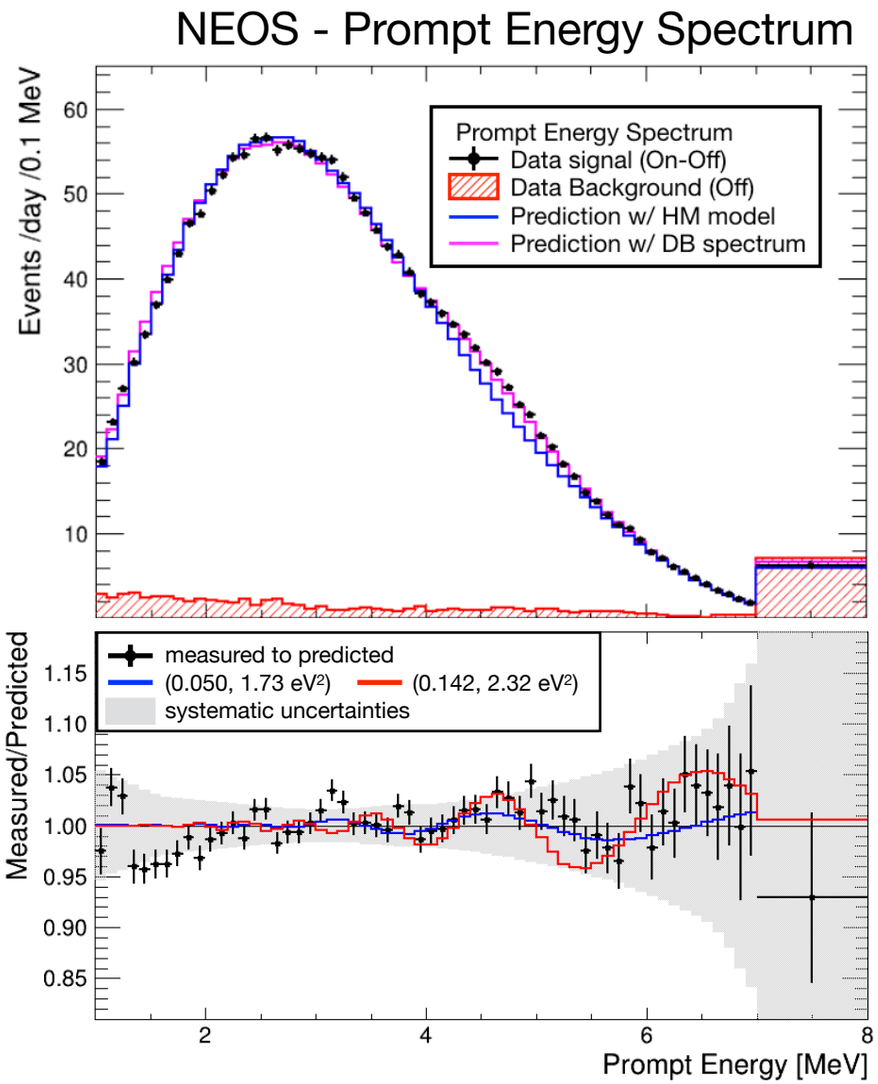
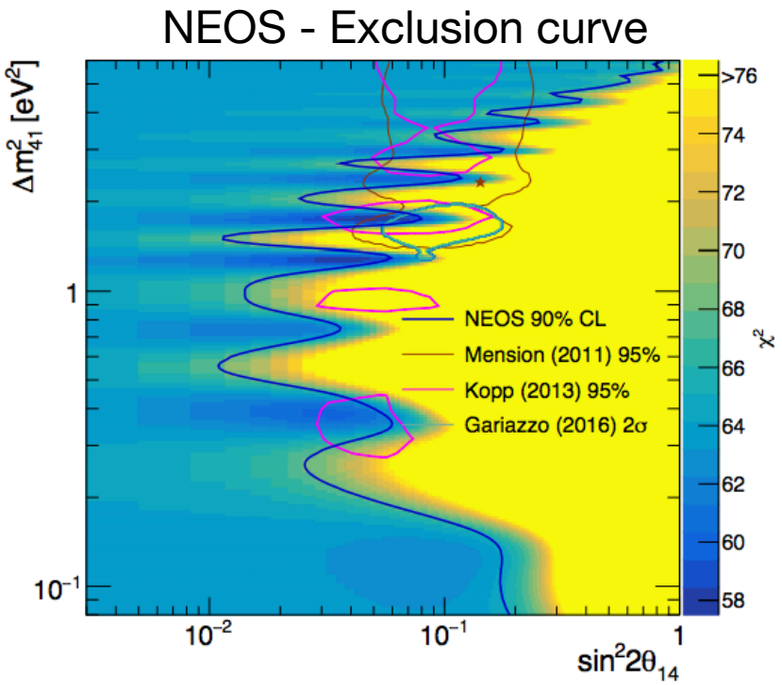
NEOS Experiment

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

NEOS-phase1

- Reactor antineutrino anomaly[1)]
  - 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)].

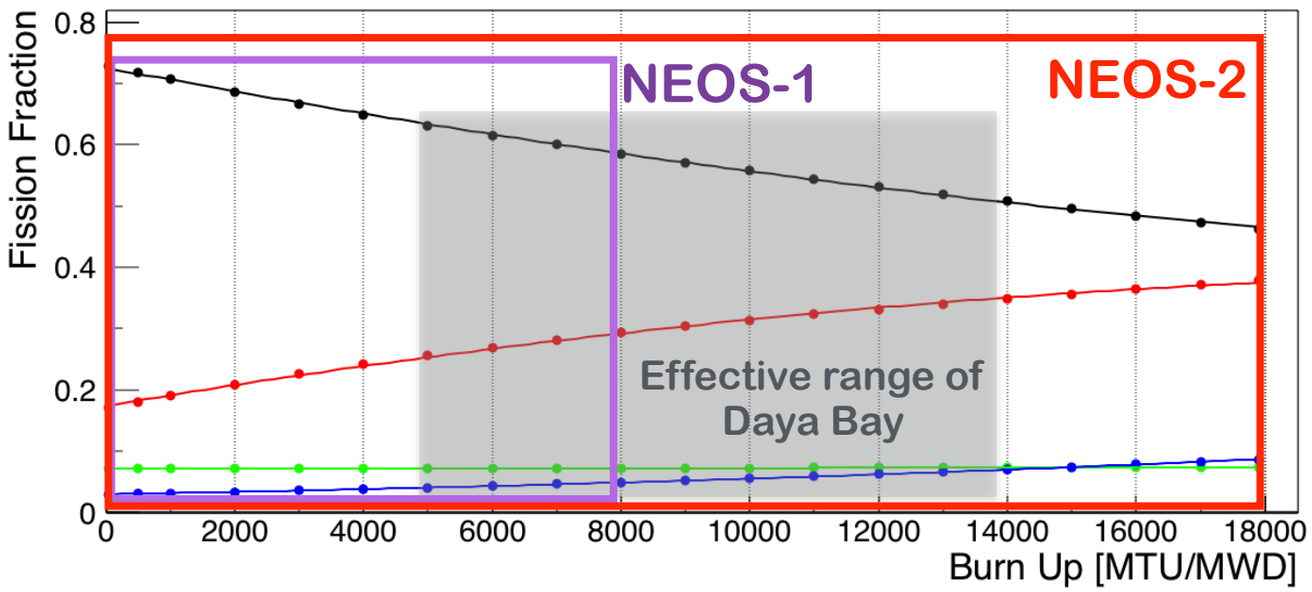




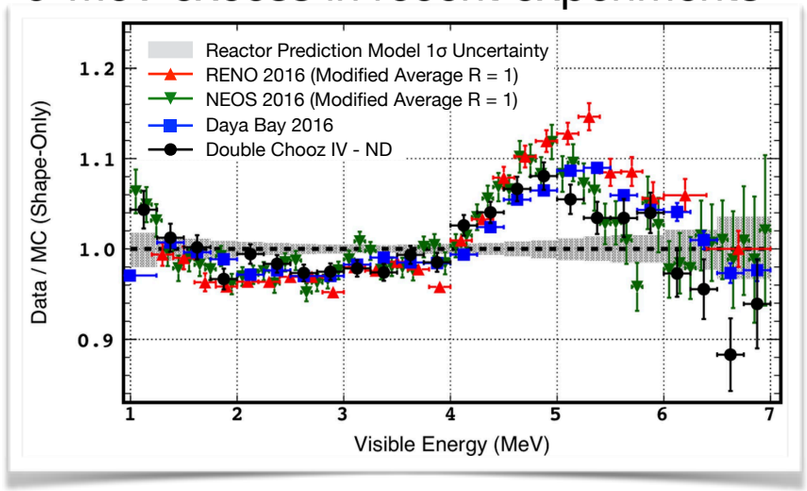
1) Phys. Rev. D **83**, 073006 (2011)
2) Phys. Rev. Lett. **118**, 121802 (2017)

NEOS-phase2

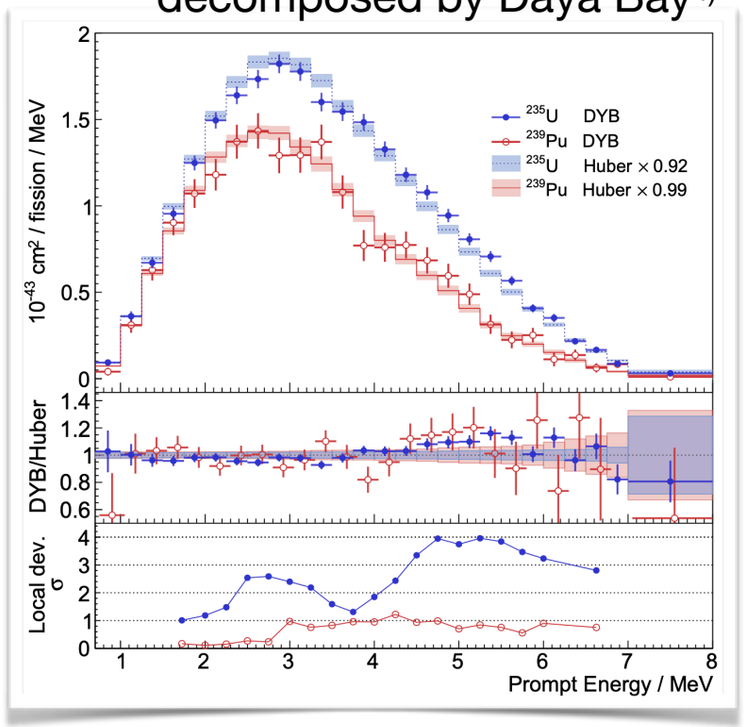
- 5-MeV excess
  - Recent experiments have observed the excess.
  - Is ^{235}U the source of the excess?
- NEOS-II
  - To understand the reactor neutrino spectrum
  - Rate+shape analysis for sterile-ν search
  - Similar uncertainty to Daya Bay is expected thanks to larger changes in fission fraction.



5-MeV excess in recent experiments[3)]



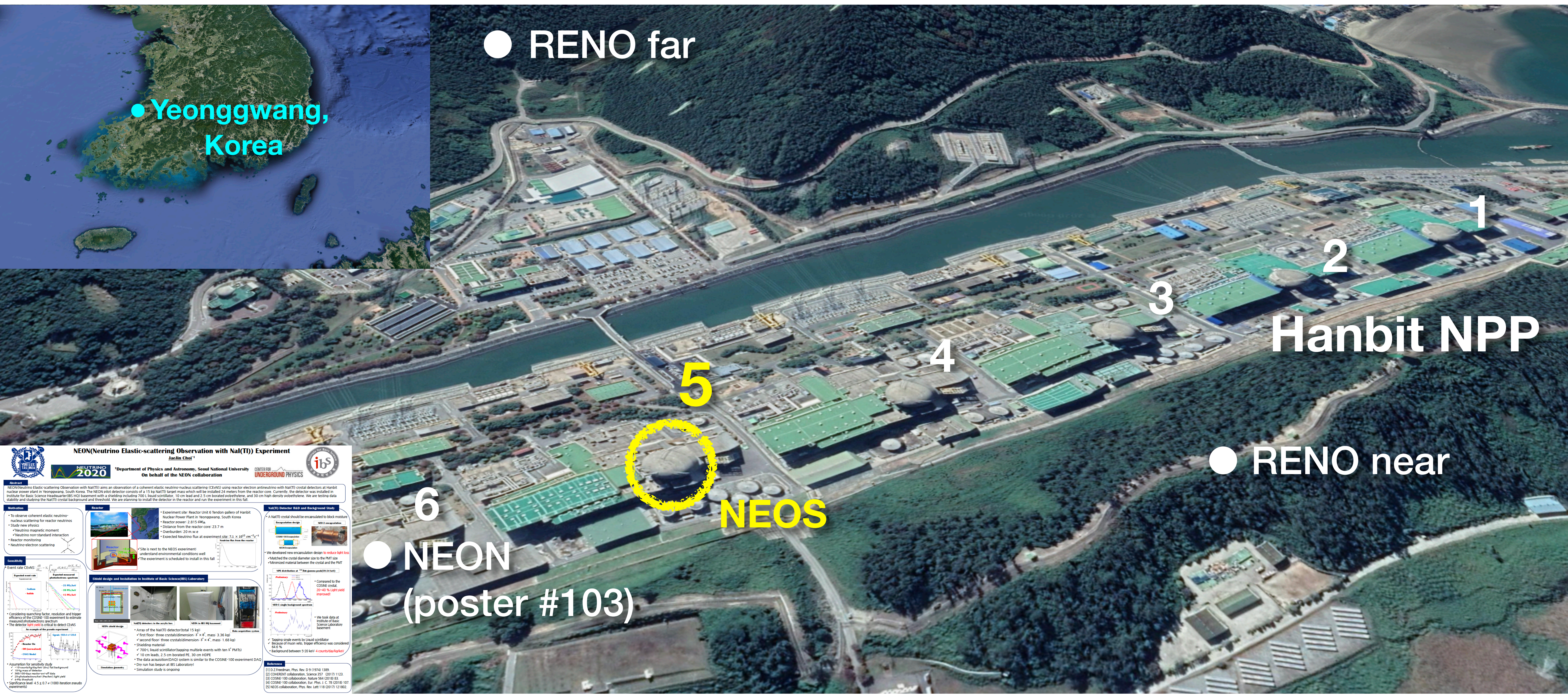
^{235}U & ^{239}Pu spectra decomposed by Daya Bay[4)]



3) Nature Physics **16**, 558-564 (2020)
4) Phys. Rev. Lett. **118**, 251801 (2017)

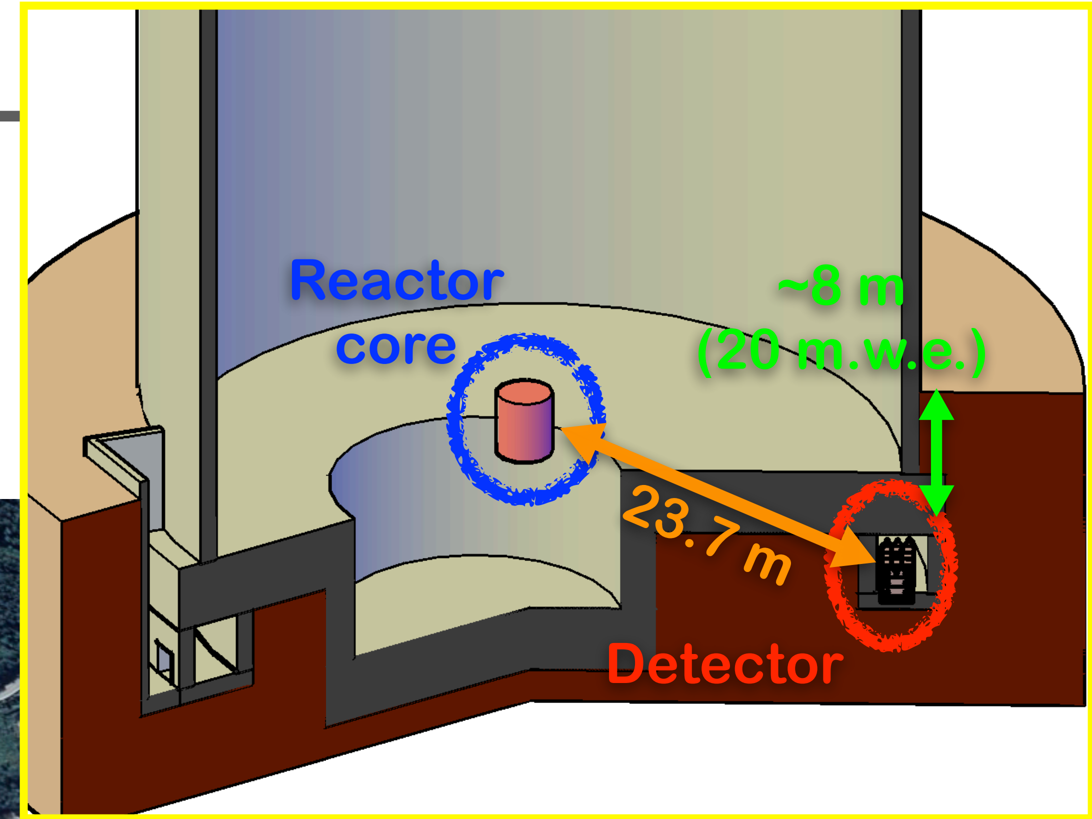
Experimental Site

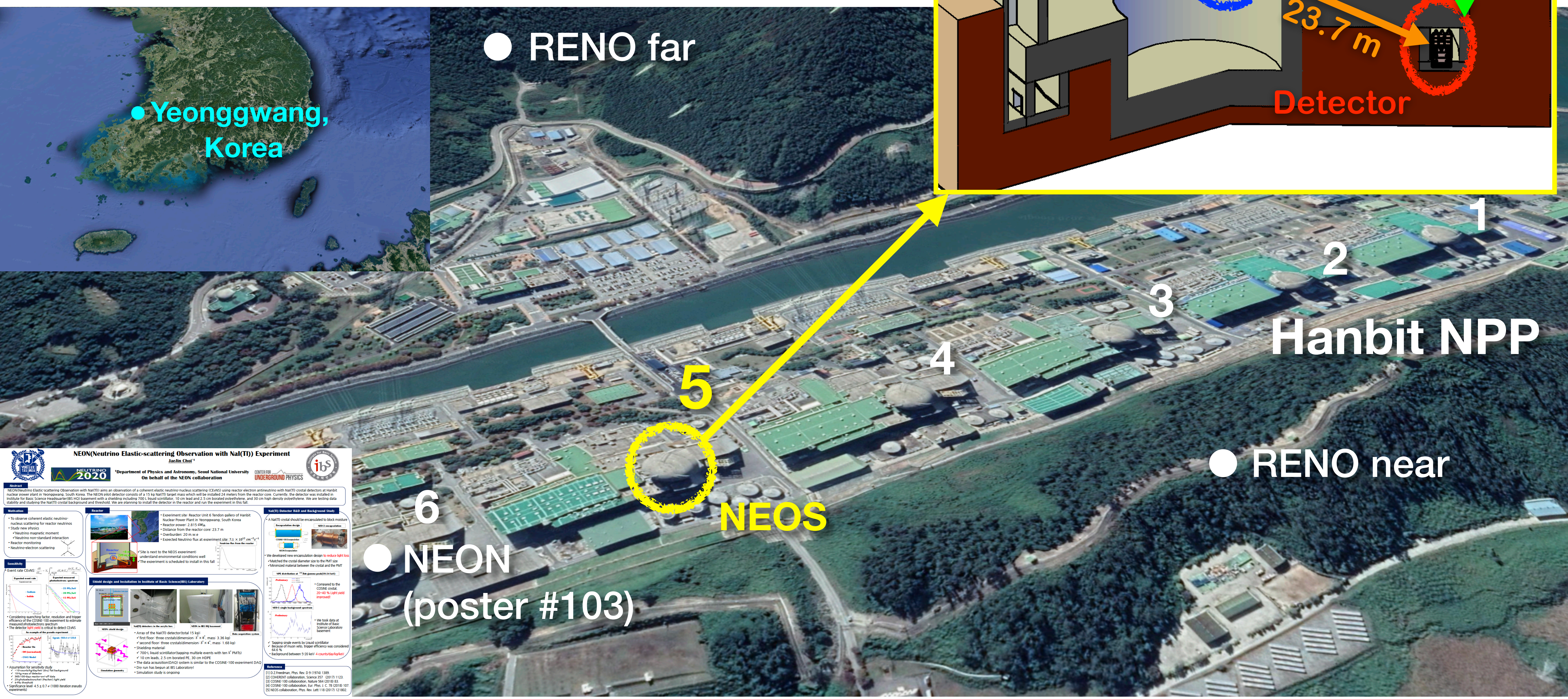
- Hanbit-5 reactor in Yeonggwang, Korea
- 2.8-GW_{th} commercial reactor
- Core size: 3.1-m diameter and 3.8-m height



Experimental Site

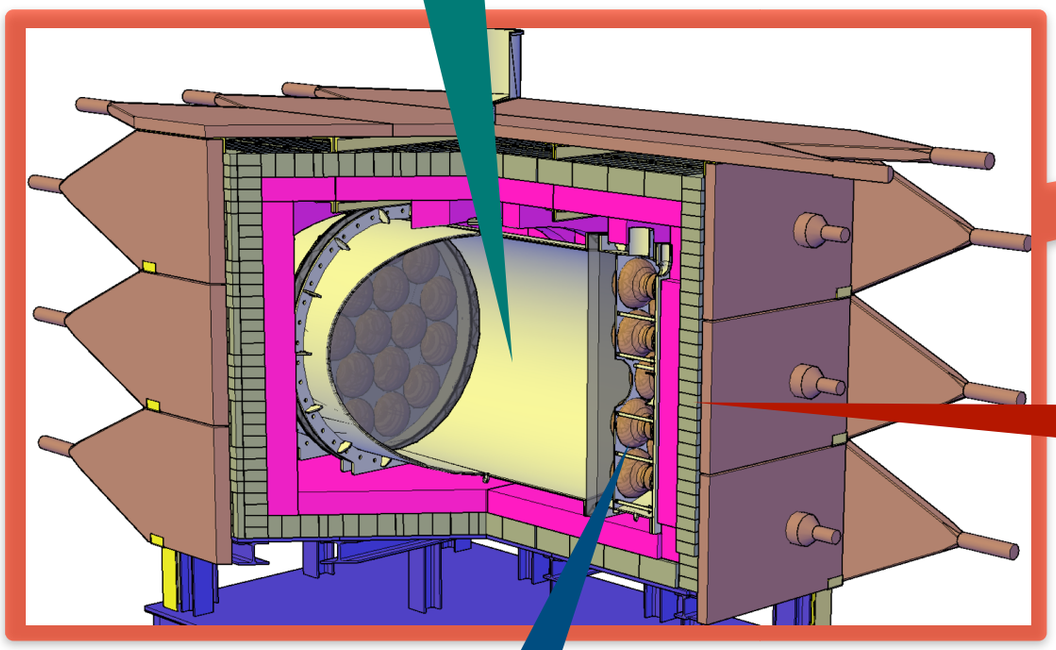
- Detector in tendon gallery
  - 23.7-m baseline and 20-m.w.e. overburden
  - Muon rate: ~1/6 of the ground (~28.7 Hz/m^2)

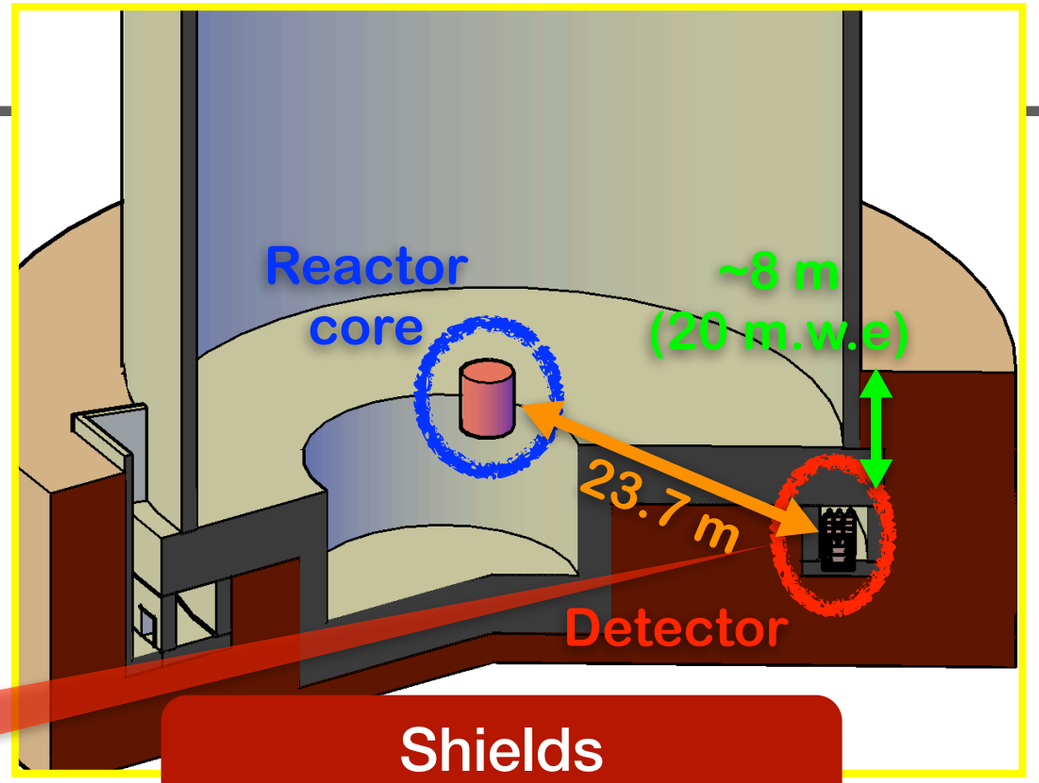




NEOS Detector

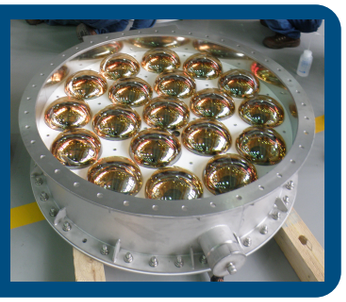
Active target
Homogeneous
1,008-L volume
0.48% Gd-LS
Mixed LS
(LAB + DIN)





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

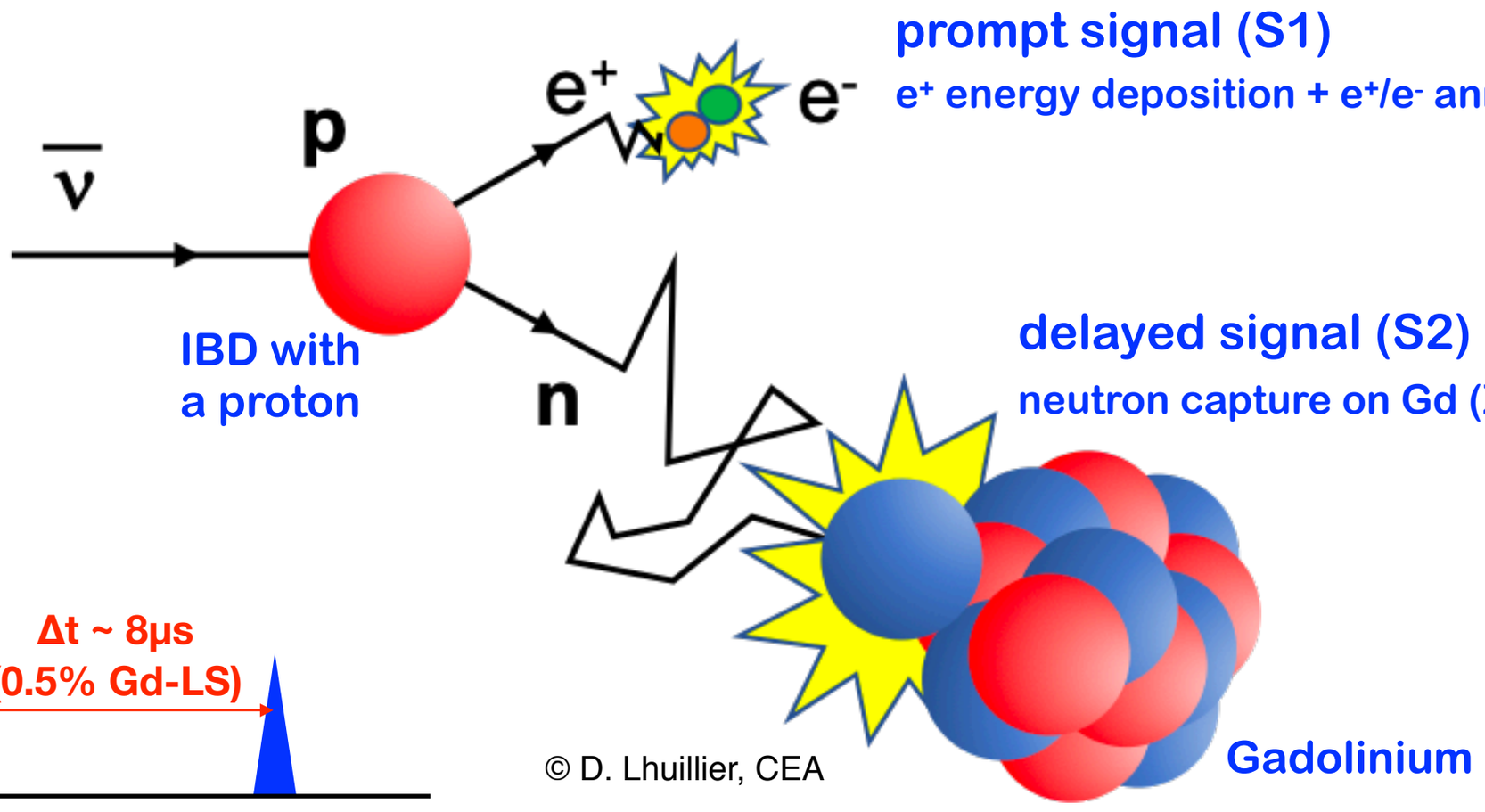
Photomultiplier tubes
Two buffer tanks at both side of target
Acrylic window b/w target & buffers
19 R5912 (8 inch) PMTs in each buffer



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

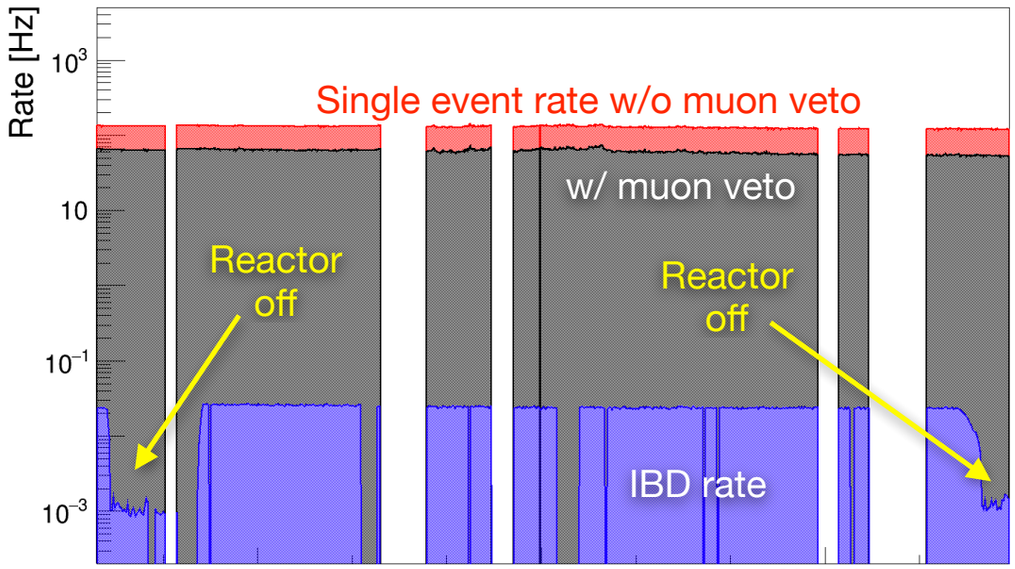
Inverse Beta Decay

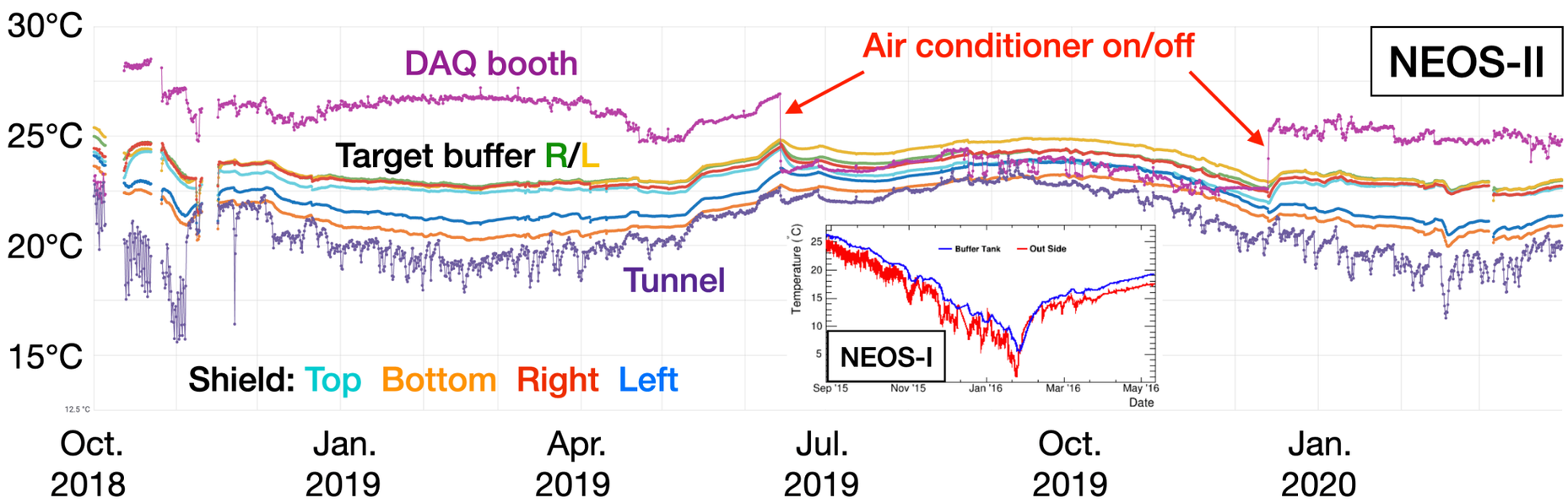
- NEOS detector is a calorimeter with Gd-LS to detect the electron antineutrino.
  - Neutrino detection through inverse β-decay (IBD) in the active target



Detector Operation

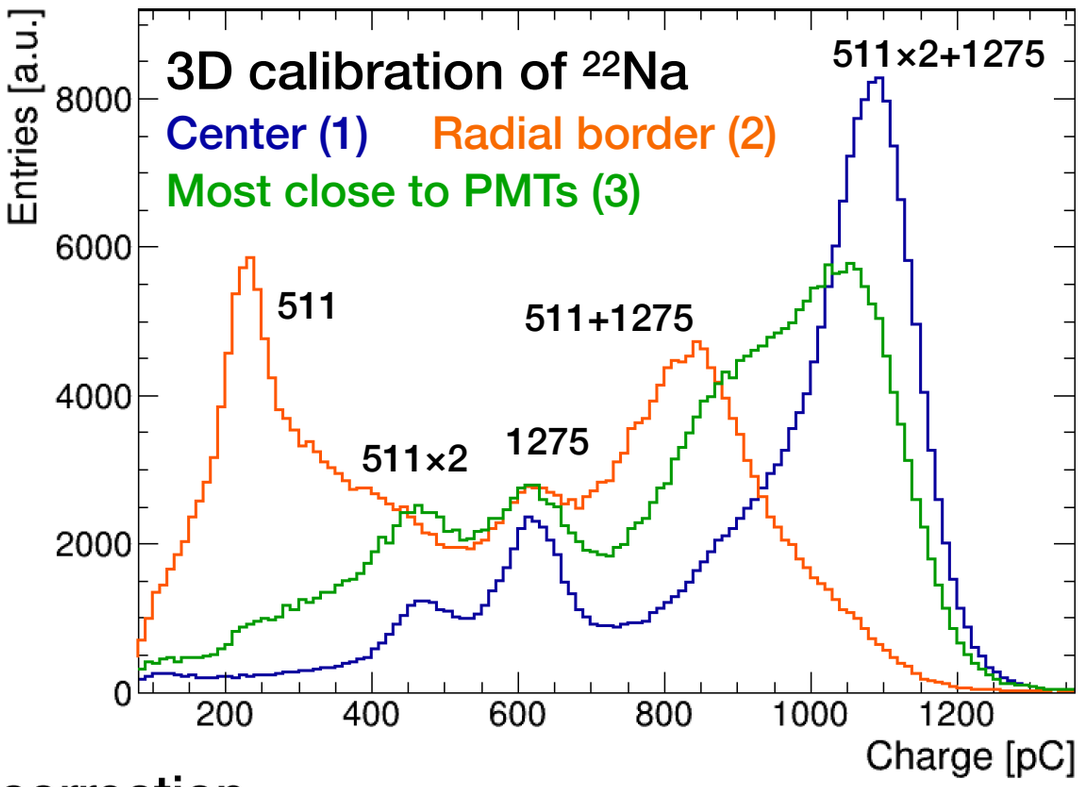
- Installation in Sep. 2018
- Temperatures of target buffers within ~2°C (~20°C in NEOS-I)
  - Air conditioner in the booth
- Data taking began in the same month.
  - The number of IBD candidates is similar to phase1.
  - ~90% DAQ efficiency
  - Data taking will be over in Sep. 2020.

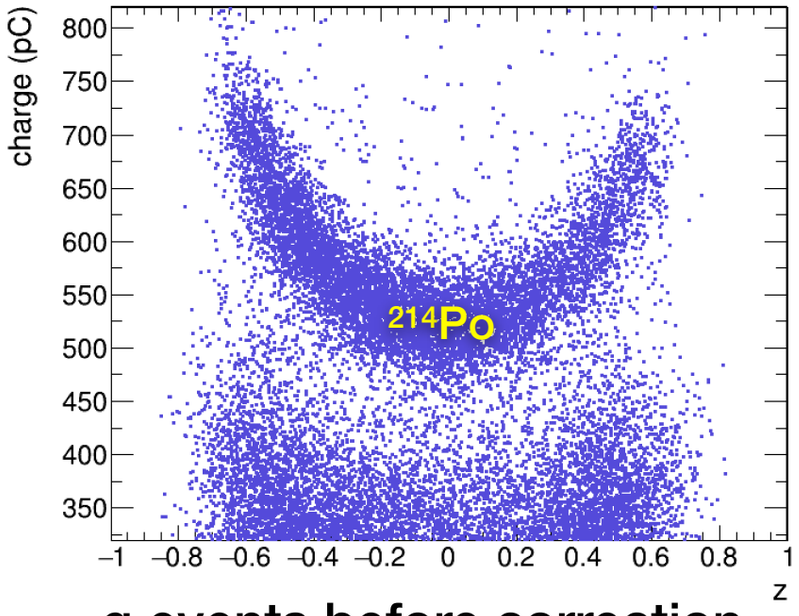




Detector Response

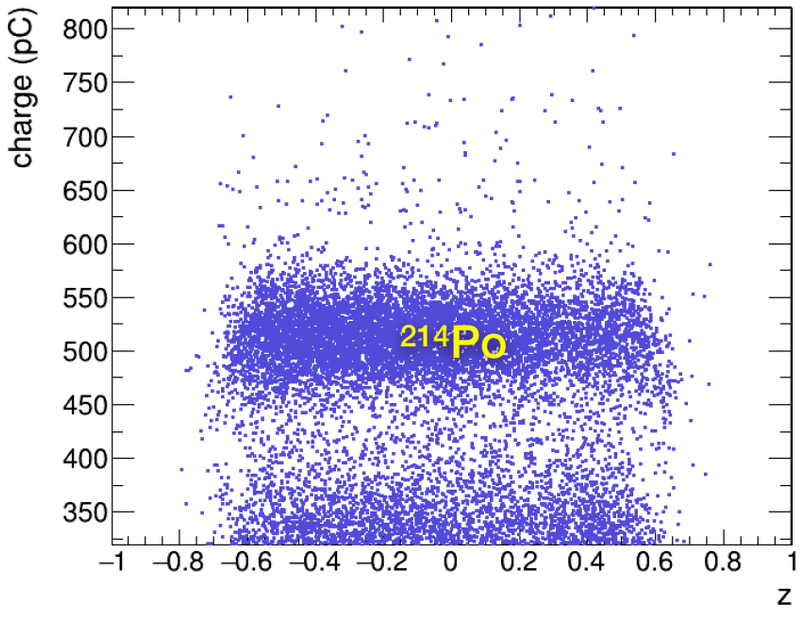
- Escaping γ events
  - It can distort energy distribution of γ events.
  - Prompt signal includes two 0.511-MeV γs.
- Non-uniformity
  - Detector response depends on position.
  - Non-uniformity is corrected with α events.

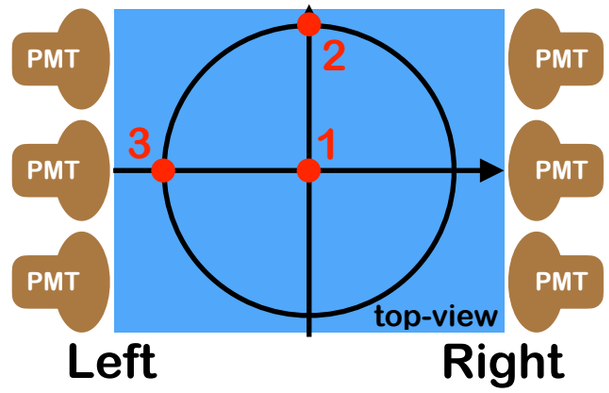




α events before correction

α events after correction

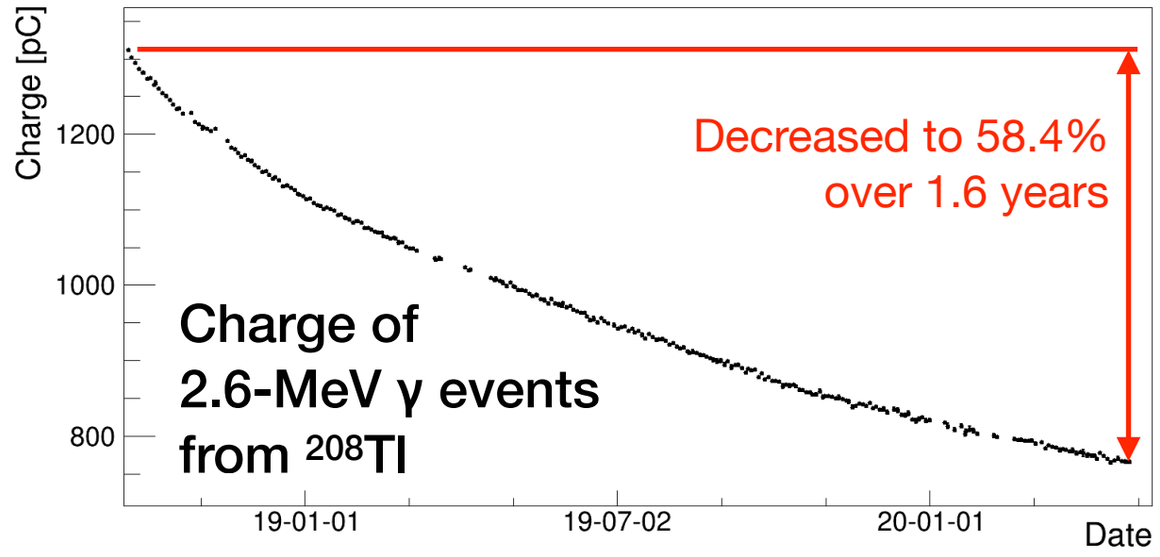


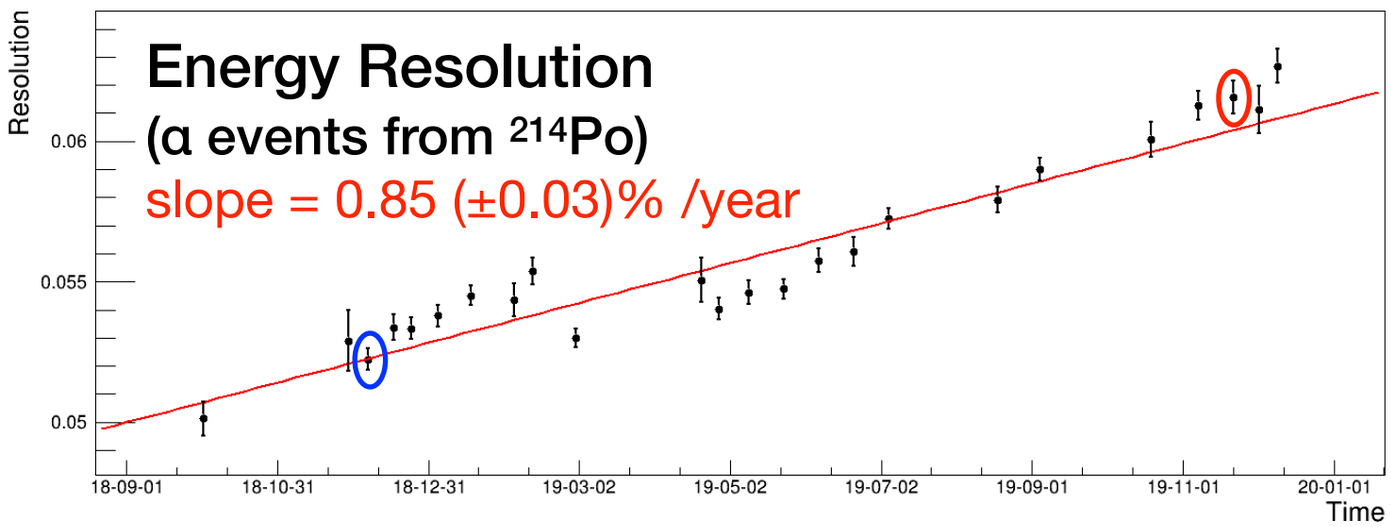


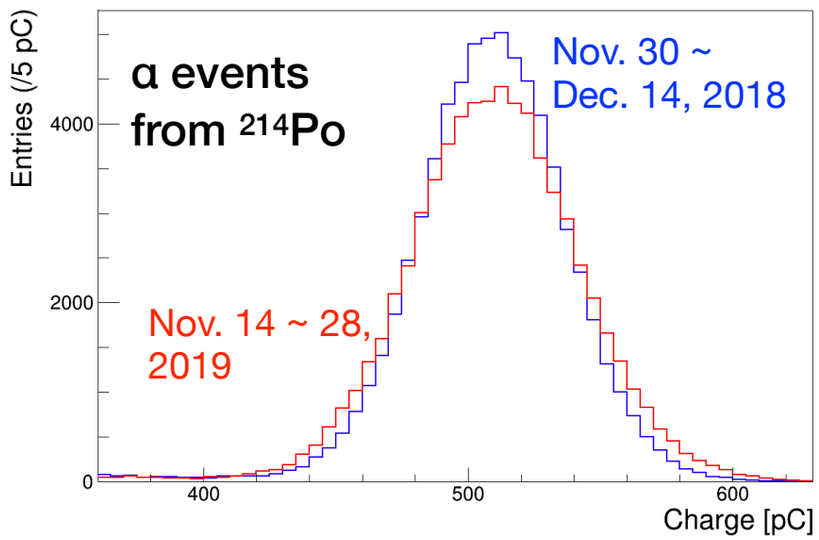
$$z = \frac{Q_{\text{right}} - Q_{\text{left}}}{Q_{\text{right}} + Q_{\text{left}}}$$

An Issue Regarding Light Yield

- Decreasing light output
  - Precipitation in a stored LS sample
  - Decreased to ~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

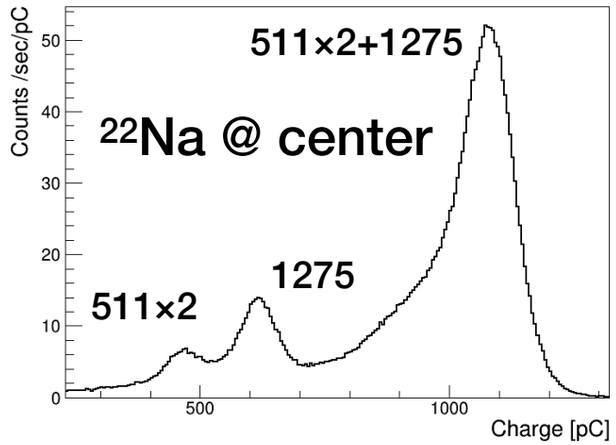


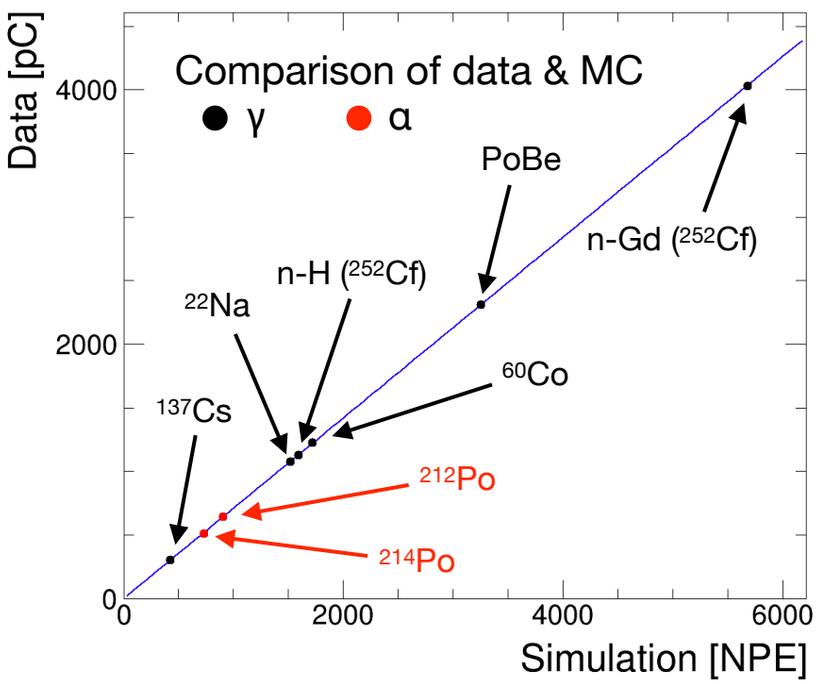


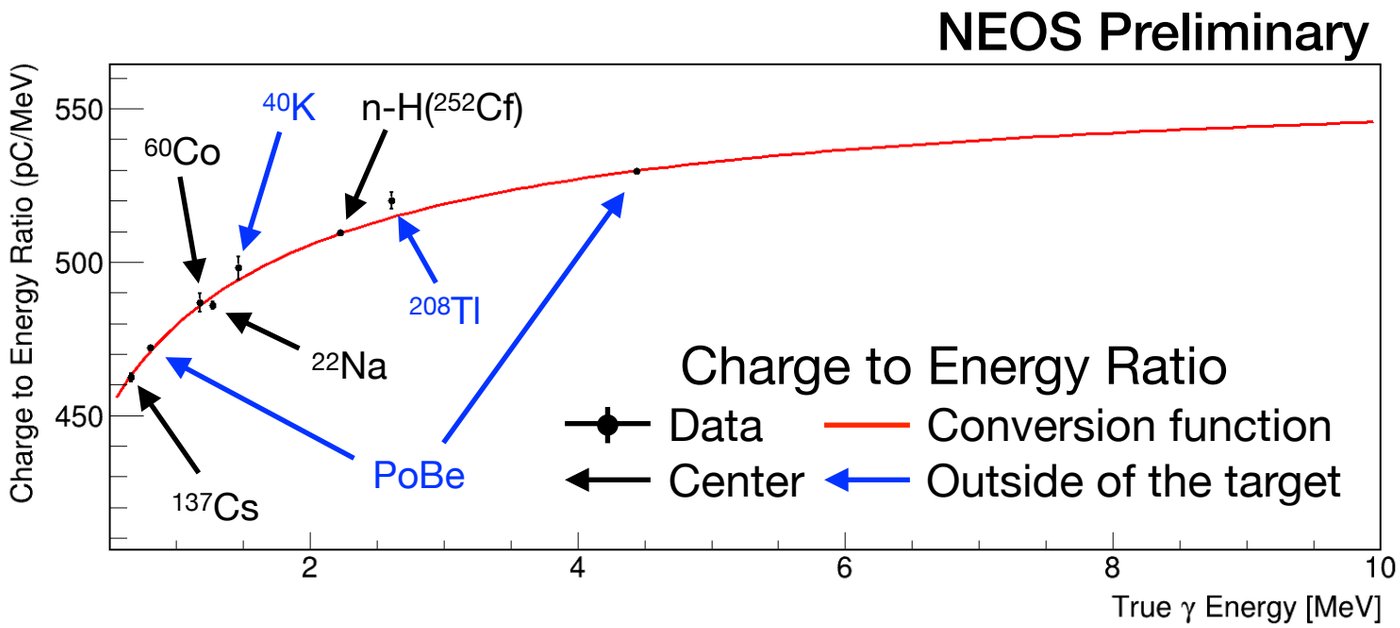


Energy Calibration

- 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.

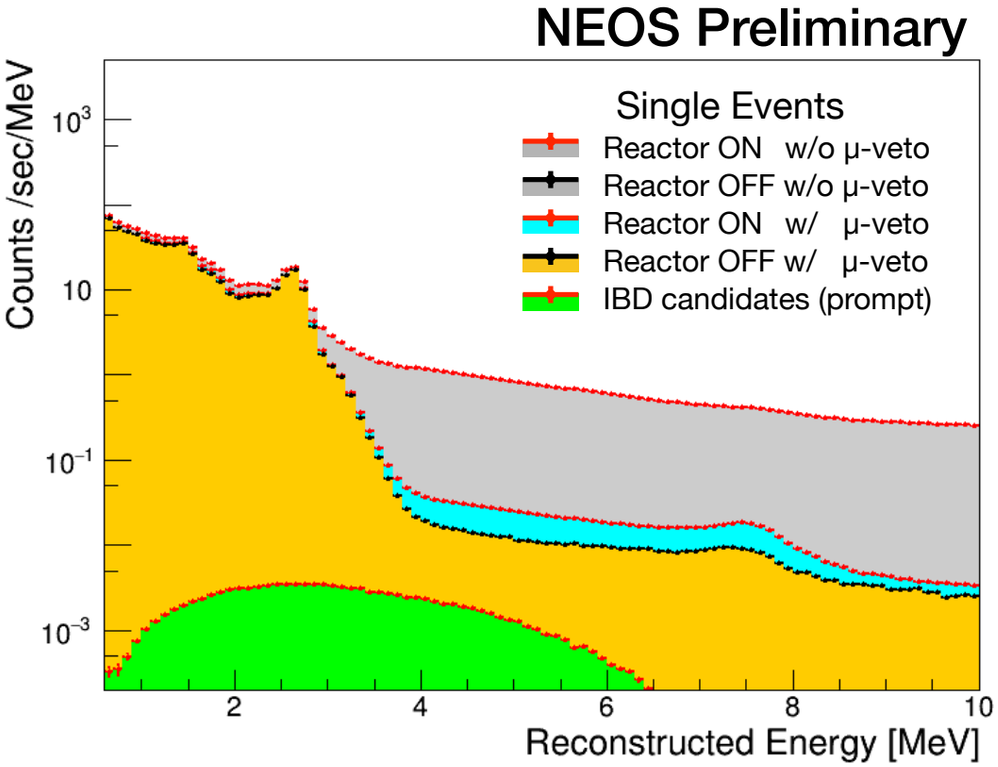


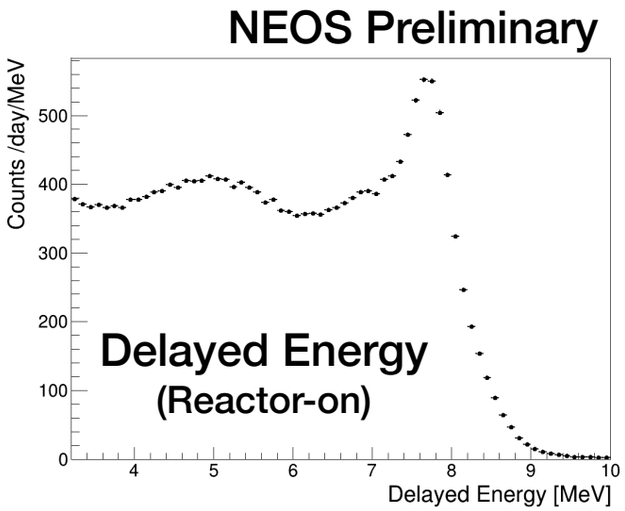


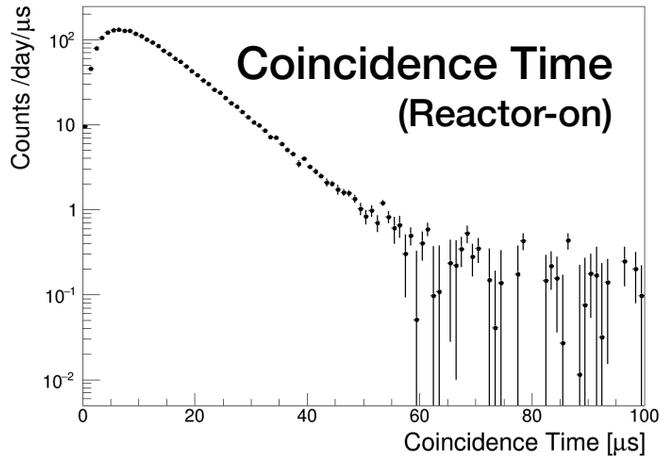


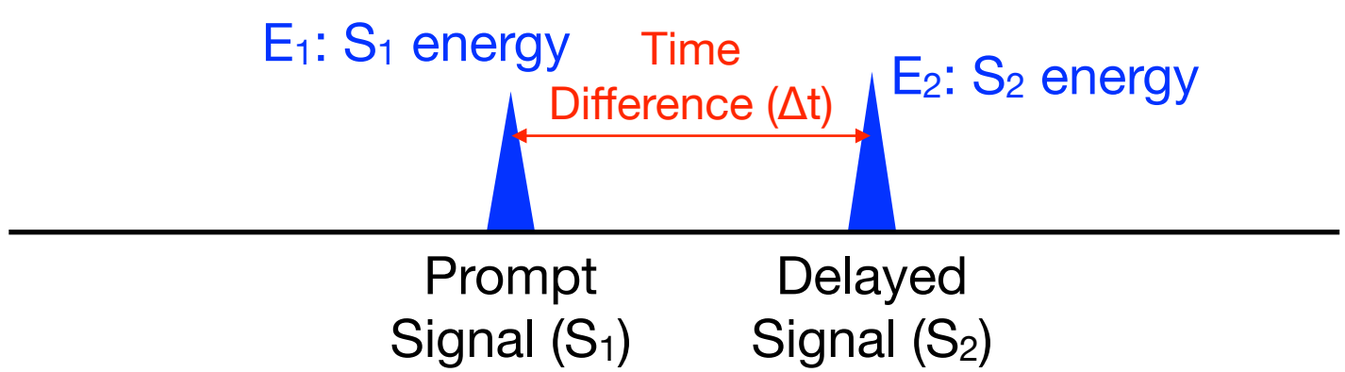
IBD Selection

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



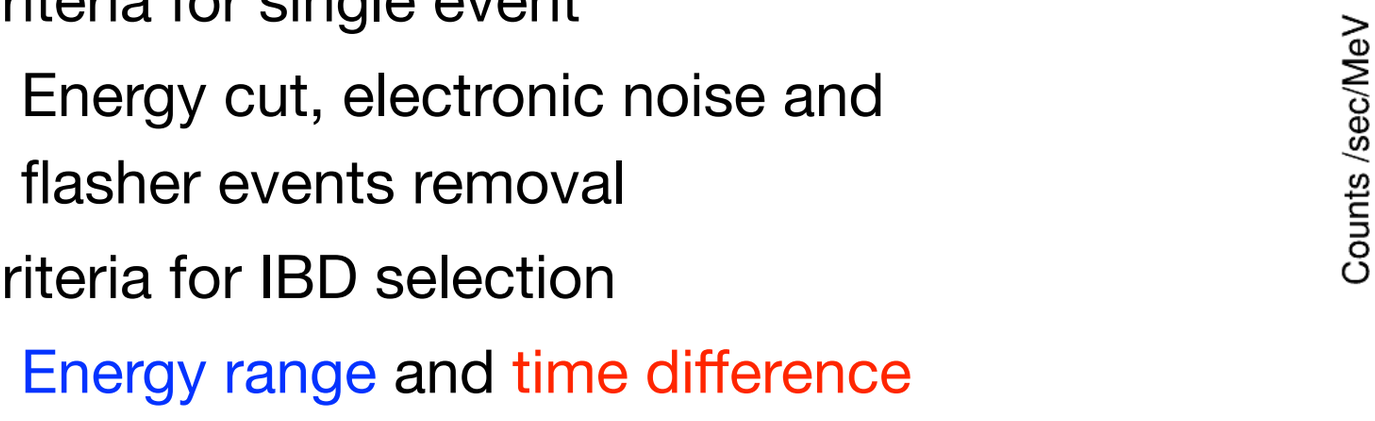


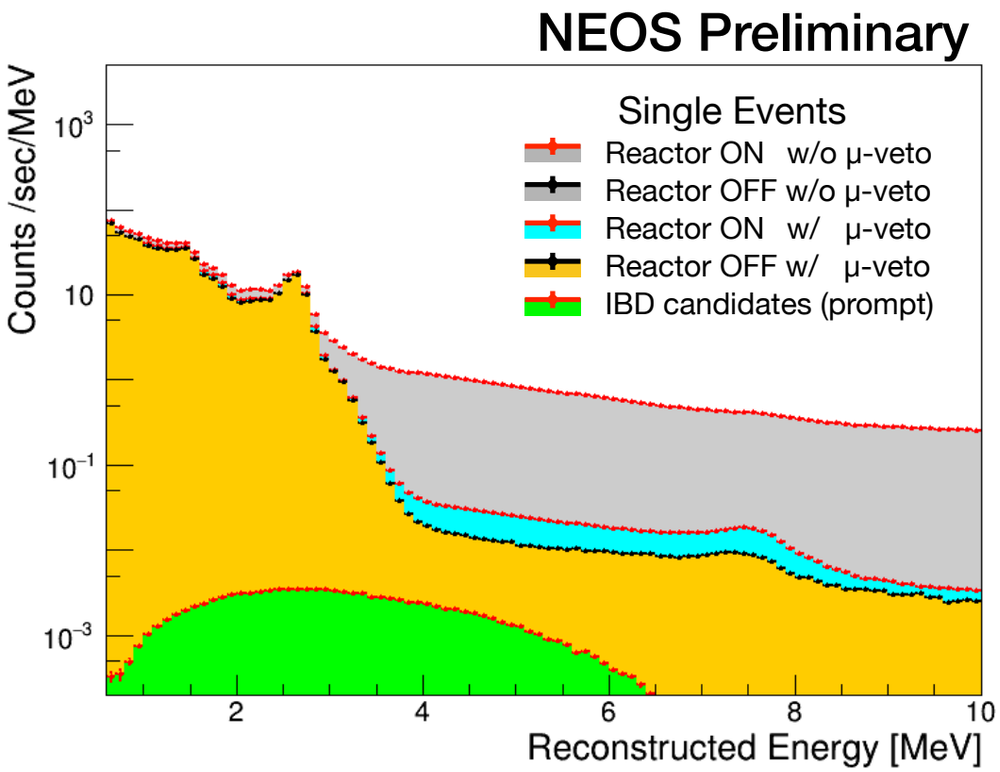


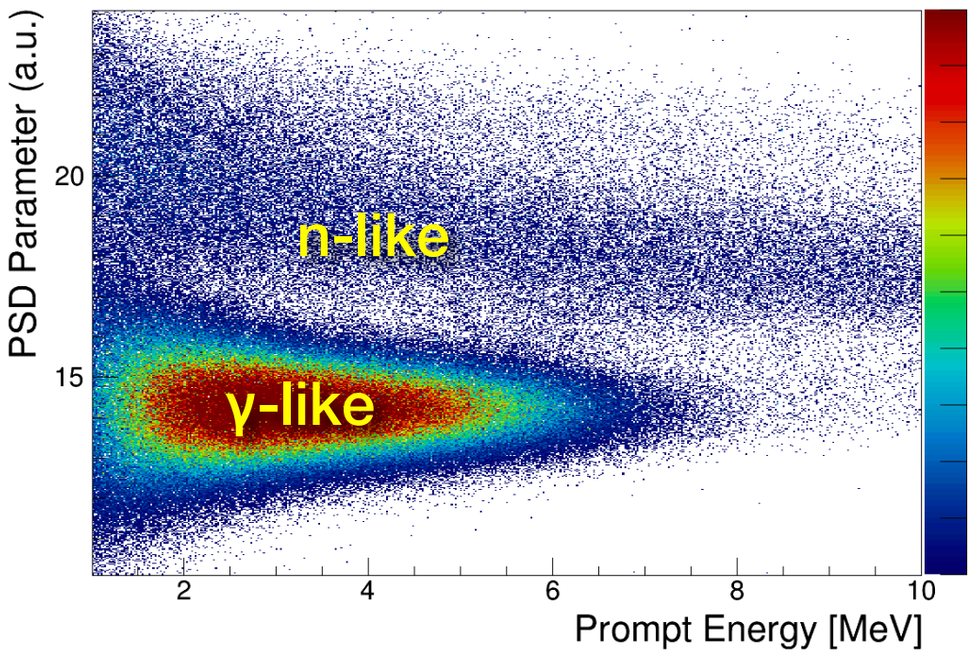


IBD Selection

- 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

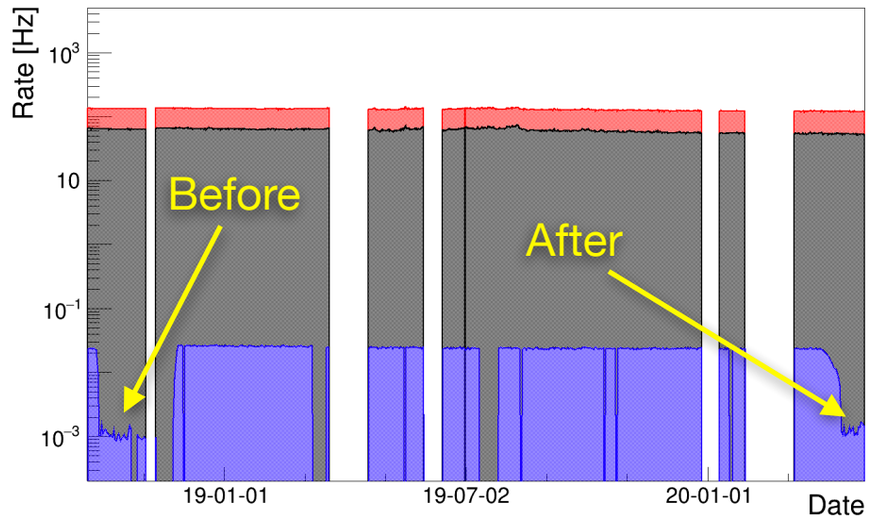


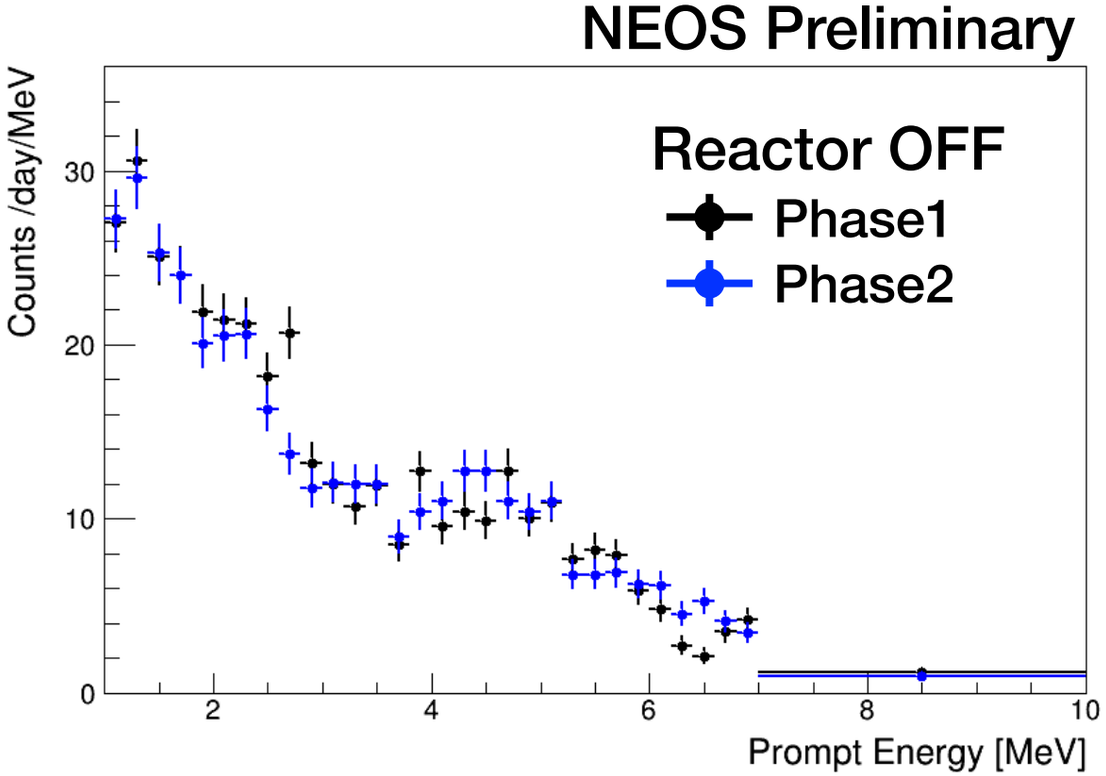


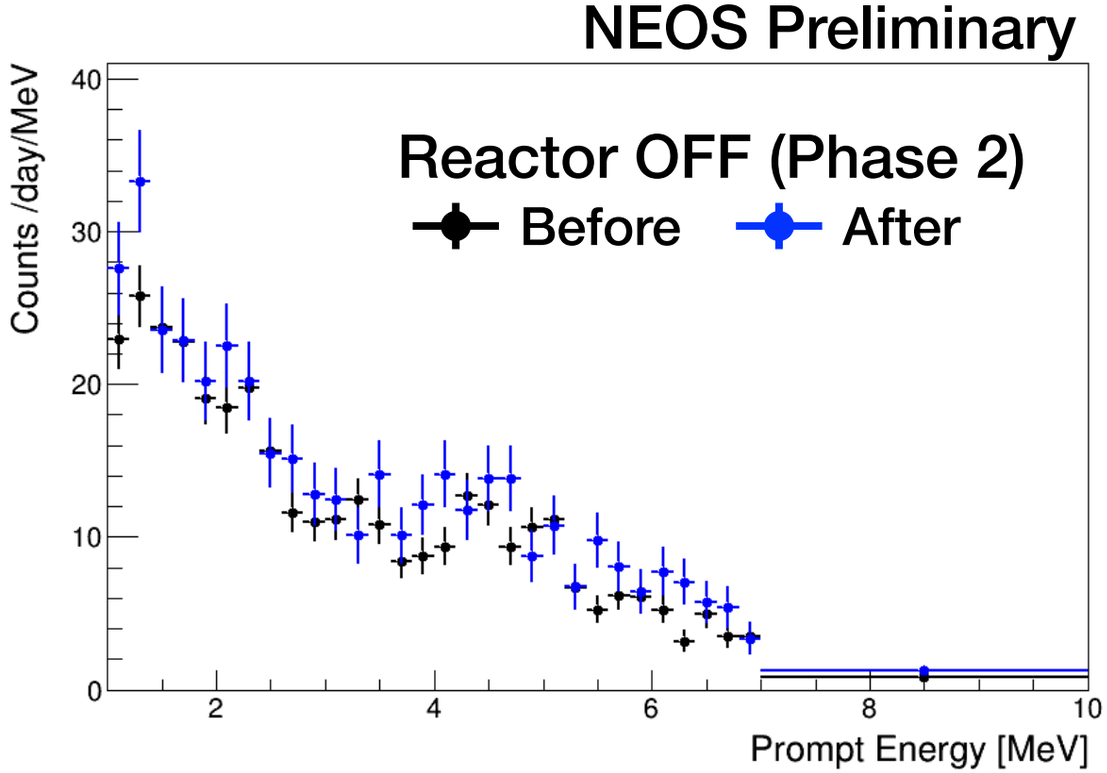


Comparison of Background

- 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.





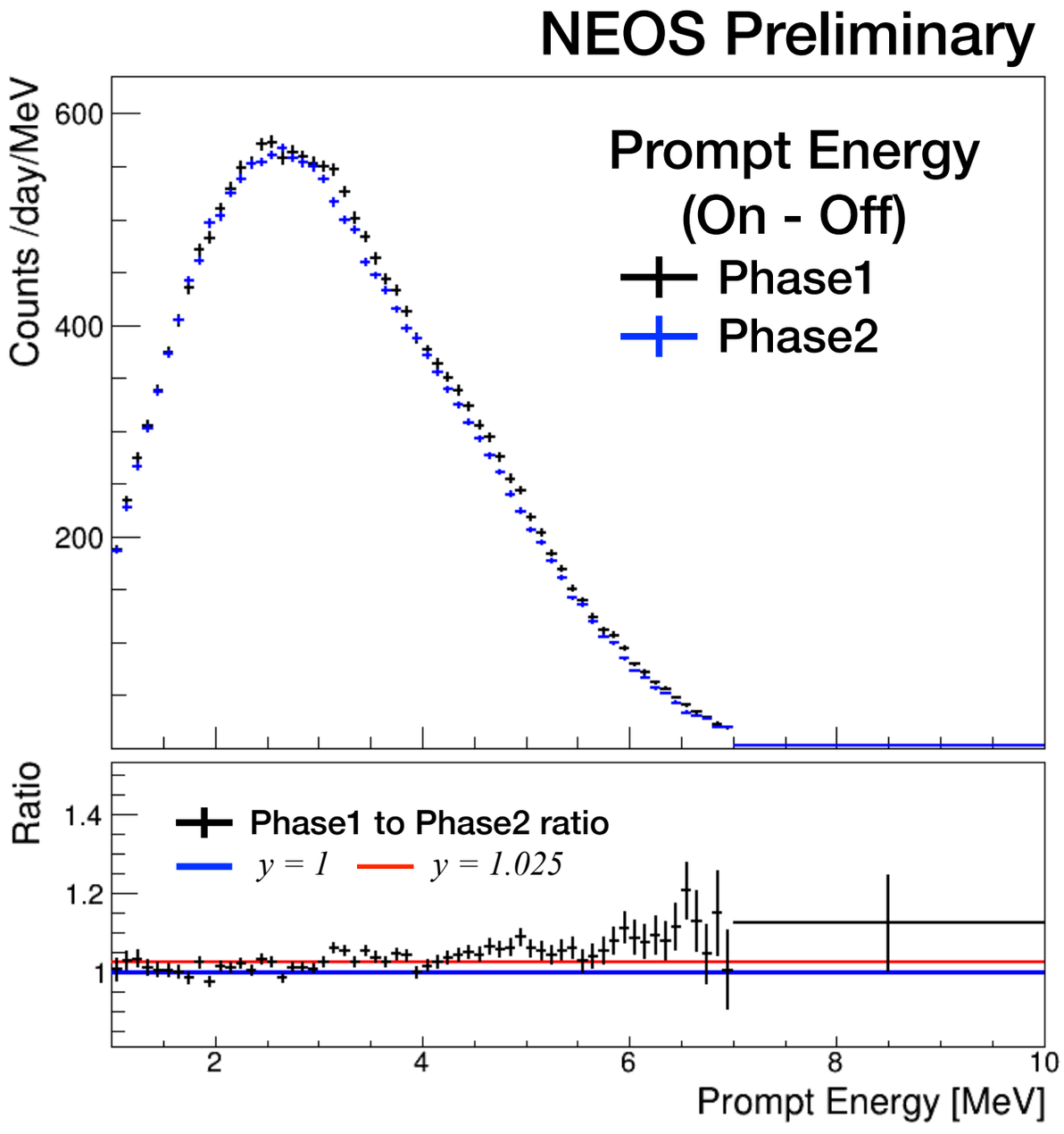


Phase1 VS Phase2

- 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)



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 !!!