Search for CEvNS Events from the NEON Experiment

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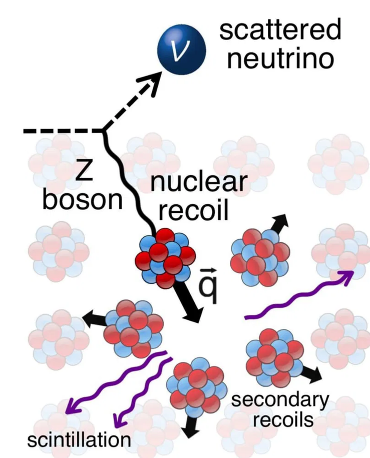
On behalf of NEON collaboration

CENTER FOR UNDERGROUND PHYSICS

1. Coherent Elastic Neutrino-Nucleus Scattering

Fermi constant Weinberg angle Form factor

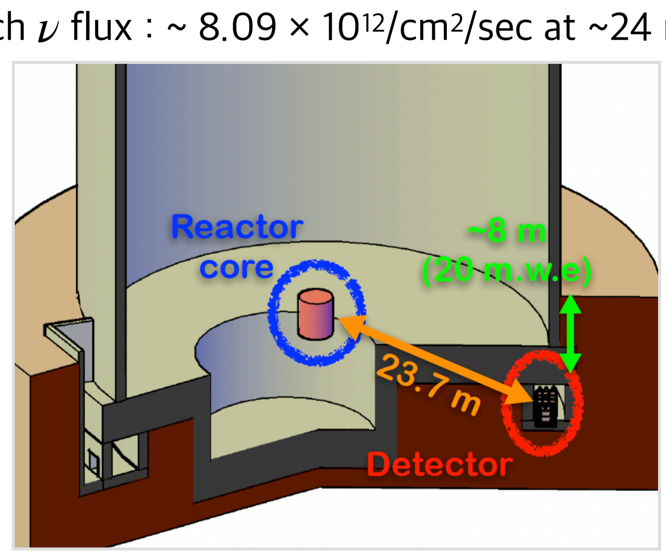
$$\frac{d\sigma(E_\nu,T)}{dT} \simeq \frac{G_F^2}{4\pi}\left[N-\left(1-4\sin^2(\theta_W)\right)Z\right]^2 F^2(q^2)M\left(1-\frac{MT}{2E_\nu^2}\right)$$

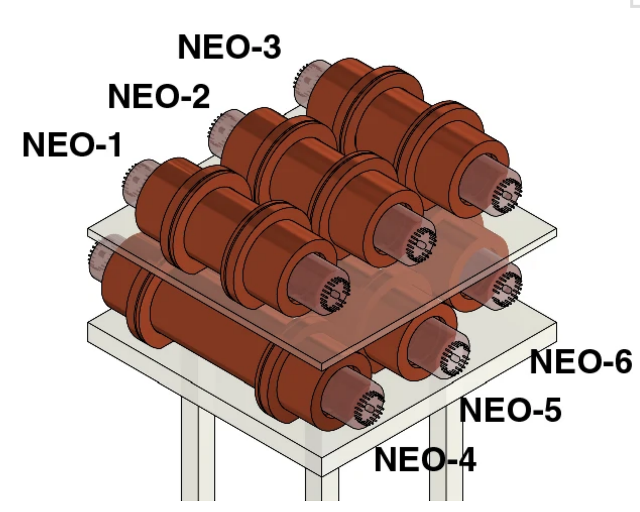


- Neutrino scatters off the nucleus as whole.
- Total cross-section is **proportional to target N^2**
- Physical potential on [neutron floor / Light mediator / Non-standard interactions ...]
- Observation History
  - COHERENT (Sapallation Neutron Source) : **CsI[Na]** (2017) & **LAr** target (2021)
  - XENONnT (Solar ^{8}B neutrino) : **(LXe) target at 2.78σ** (2024)
  - CONUS+ (reactor neutrino) : **(HPGe) target at 3.7σ** (2025)

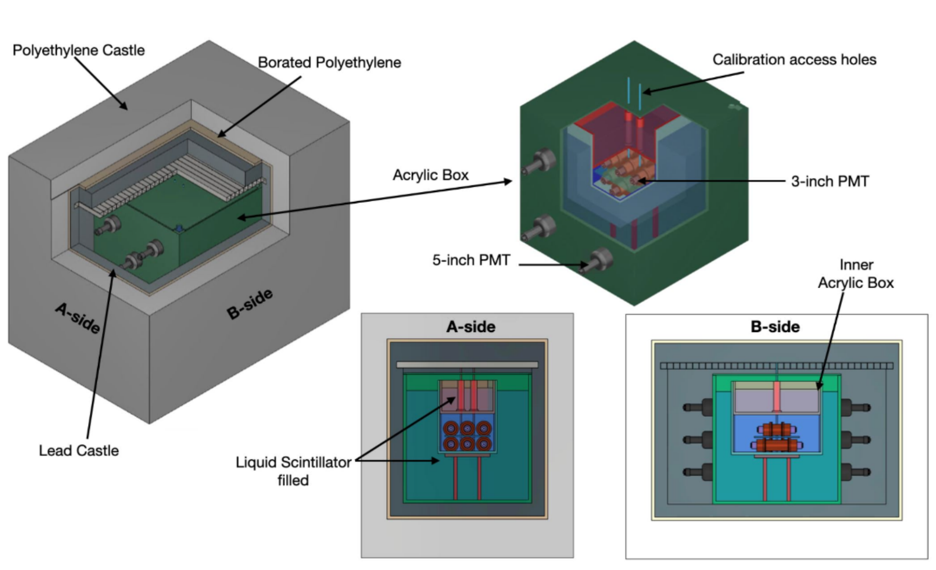
2. NEON experiment

*Rich $\bar{\nu}$ flux : ~ 8.09 × 10^{12}/cm²/sec at ~24 m

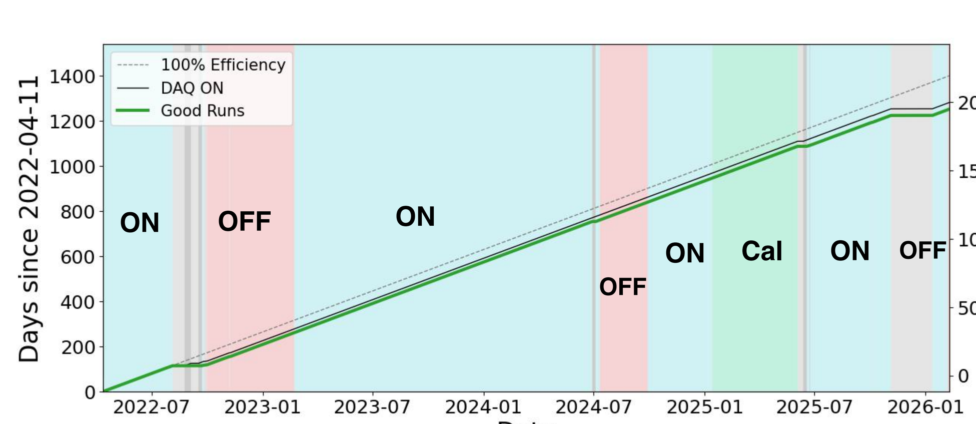


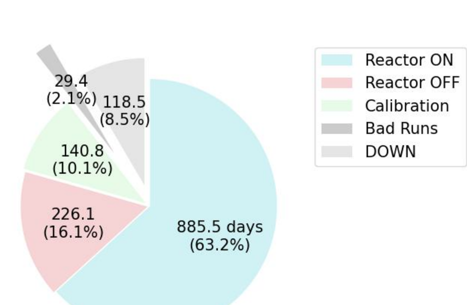


- Reactor neutrino experiment, aims to find the CEvNS to Na target of NaI(Tl) crystals
- Installed at tendon-gallery of Hanbit nuclear power plant in Korea
- 6 NaI(Tl) targets, with high light yield (~ 25 p.e / keV) *p.e = photoelectrons



- Passive shields
  - 20/30 cm thick Polyethylene [PE]
  - 2.5 cm thick Borated PE
  - 10/15 cm thick lead shield
- Active shield
  - 800 L Liquid scintillators in Acrylic box
  - 10 of 5 inch PMTs
  - Passive trigger for background tagging.



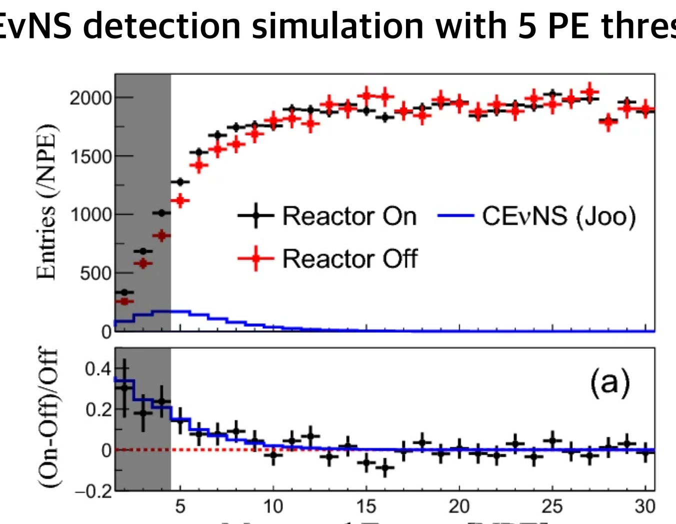


Running from April 2022.

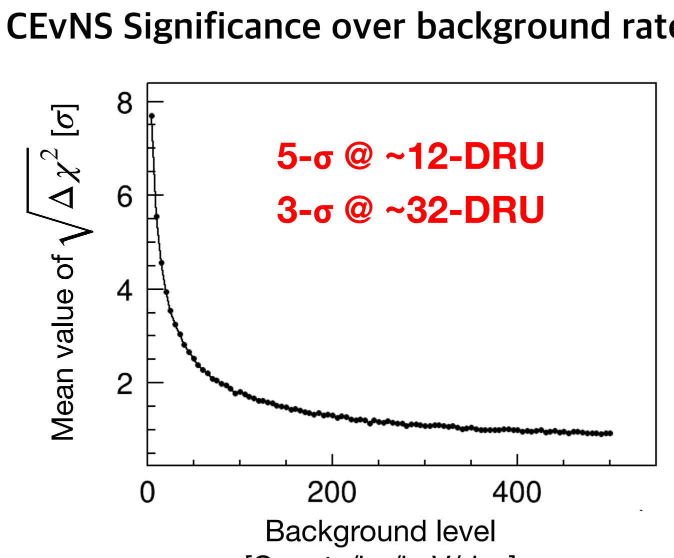
- ~18563.72 kg·day exposure & ON/OFF data : 886/226 days
- Data taking will be stopped in Fall 2026.

3. CEvNS detection strategy

CEvNS detection simulation with 5 PE threshold



CEvNS Significance over background rate

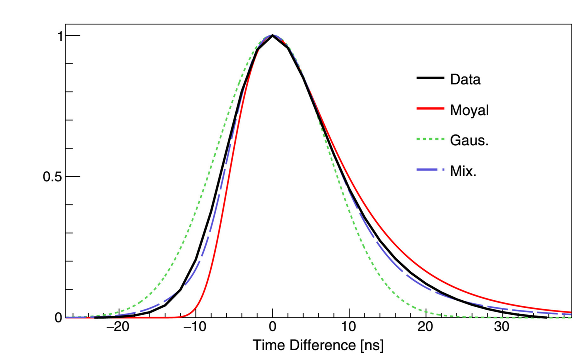


- CEvNS events can be derived by 'On - Off' data strategy.
- Requirements for 3σ CEvNS observation in NEON,
  - 5 photoelectrons (P.E.) , ~ 200 eV threshold
  - Stable background rate over time
  - Background level < 32 counts/kg/keV/day @ 5 PE level.

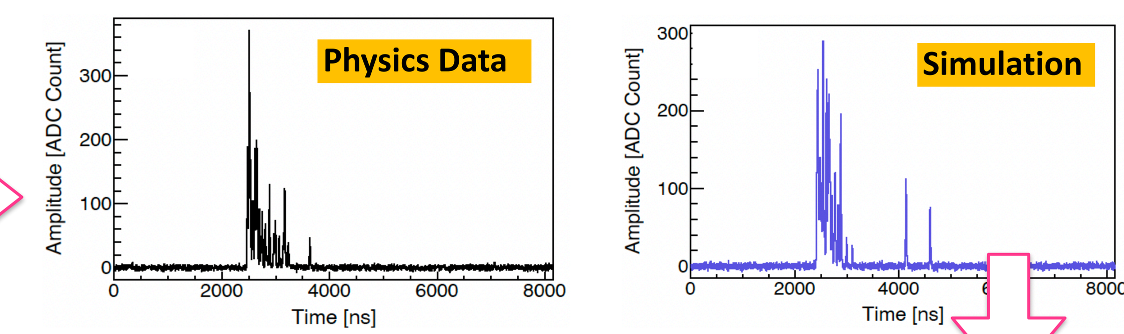
Noise selection strategy required!

4. Waveform simulation

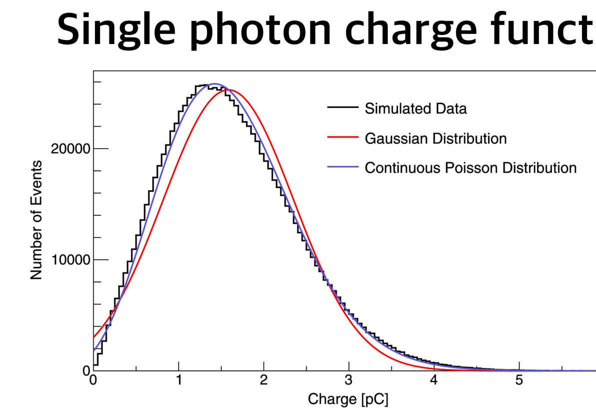
Single photon pulse function



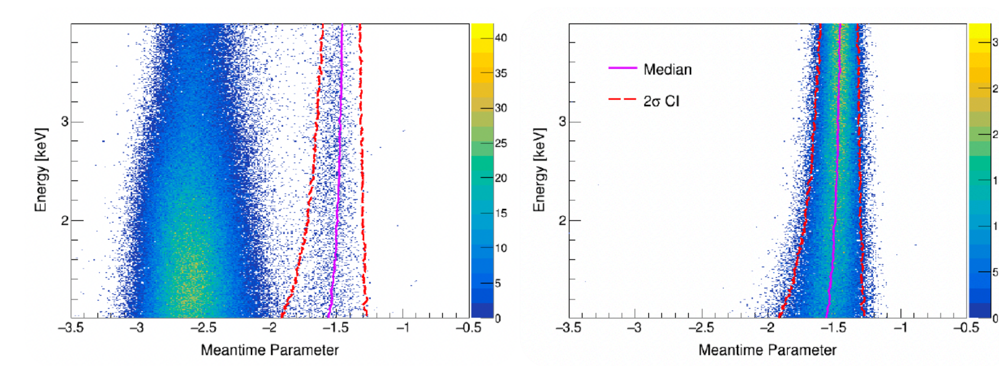
Waveform simulation example



Single photon charge function



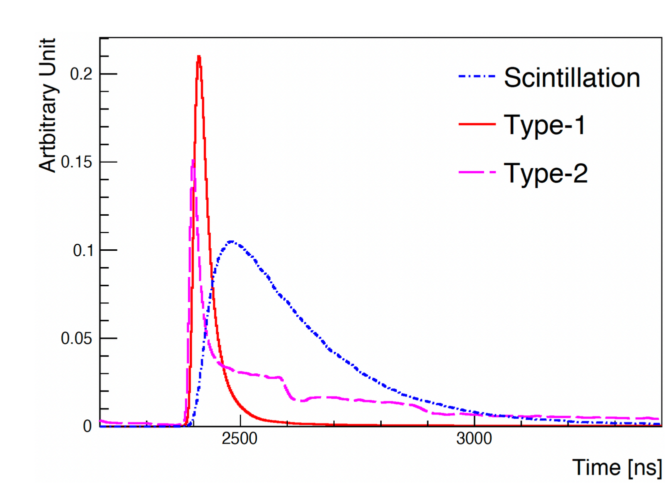
Validation using PSD parameter



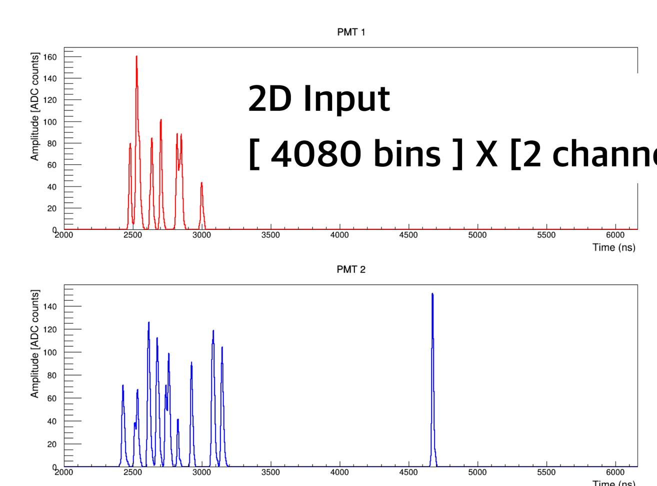
- Waveform simulation with precisely modeled single photon pulse / charge / time distribution.
- Validated with PSD parameters showing consistent distribution w/ real scintillation.

5. Deep-Learning for noise selection

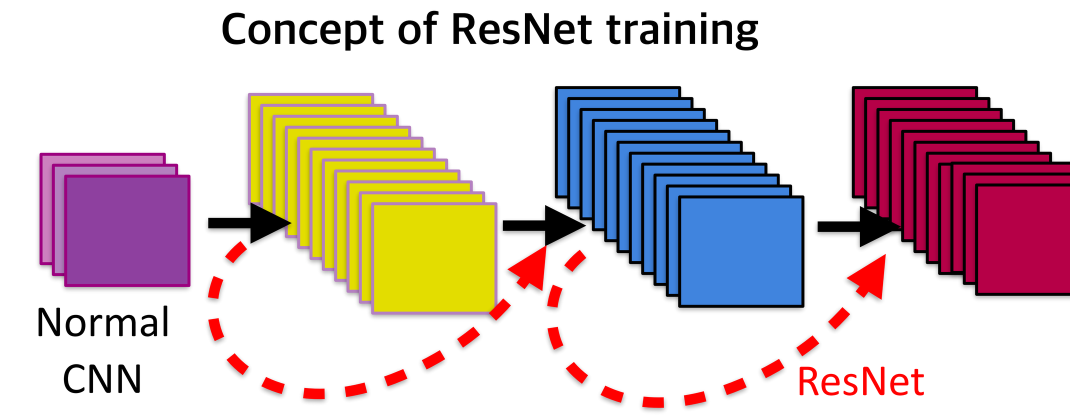
Accumulated waveform of each event type



- Type 1 (PMT-induced noise)
  : Short pulses (< 50 ns), fast decaying distribution → easy to be separated.
- Type 2 (Phosphorous events)
  - Slowly decaying distribution → hard to be separated from scintillation.



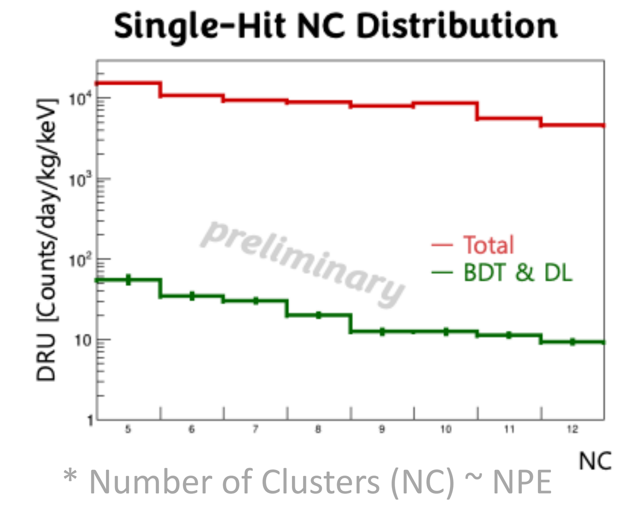
Concept of ResNet training



- Waveform classification : long & complicated event structure →requires 'deep network'
- **ResNet : avoid gradient-vanishing, using 'residual connection'**
- ResNet enables deep convolutional layers of CNN training.
- Training sample : WF simulation (Signal) & Data (Noise)

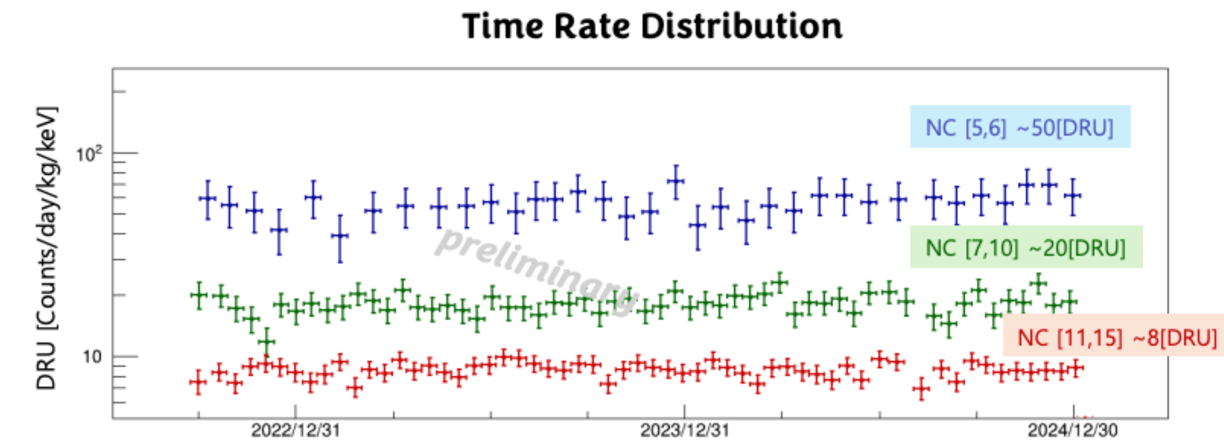
6. After selection & Future plan

Single-Hit NC Distribution



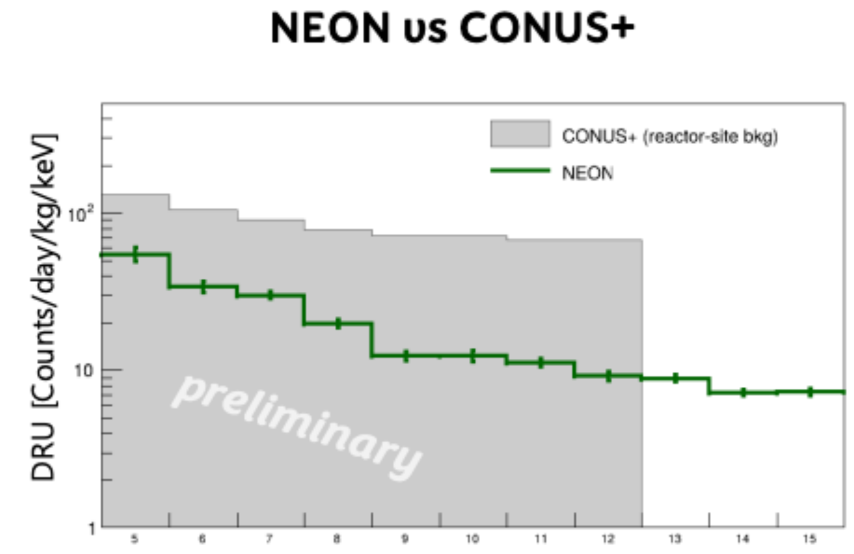
* Number of Clusters (NC) ~ NPE

Time Rate Distribution



- DL score based selection has been applied, and checked stable event rate over time.
- ~ 50 DRU at 5 PE level has been achieved, and fine-tuning for lower rate is ongoing

NEON vs CONUS+



- Our background level is comparable to or better than that of CONUS+ above NC5.
- We will model the background using Reactor-Off data and apply a likelihood fit to the On-period data to extract the CEvNS signal.