Status of NEOS Experiment

Jinyu Kim

Sejong University

on behalf of NEOS Experiment

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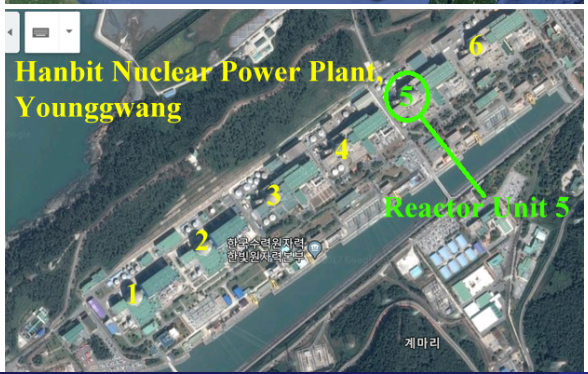
Contents

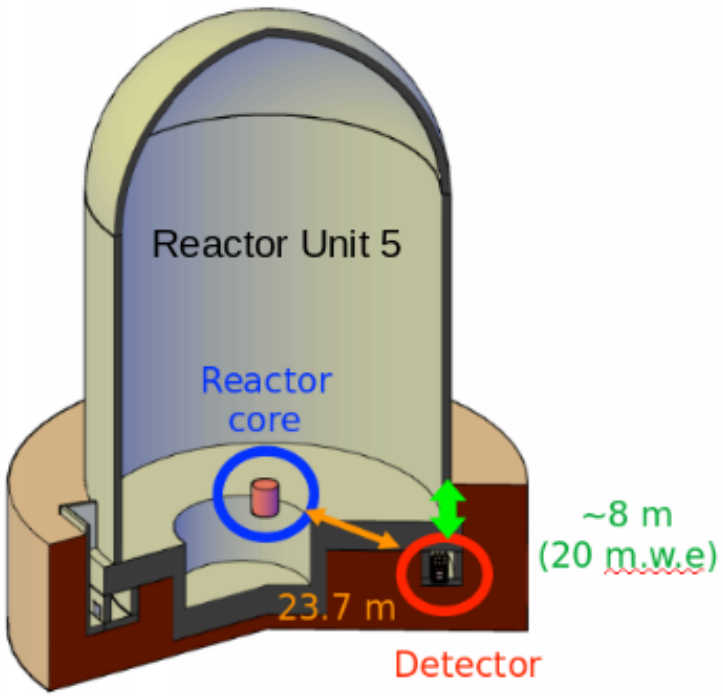
NEOS Experiment

- Neutrino Experiment for Oscillation at Short baseline.
- ν Source : Reactor unit 5 in Hanbit Nuclear Power Plant, Yeonggwang, Korea
  → Low enriched uranium fuel, 2.8 GW_{th} commercial reactor
- Detector deployment : Tendon gallery (˜23.7 m from reactor core unit 5)
- Data Taking Period
  → NEOS Phase-I : Sep 2015 ˜ May 2016 (180/46 live days with reactor on/off, Completed)
  → NEOS Phase-II : Sep 2018 ˜ (500 live days, full fuel cycle, Running)

- Location

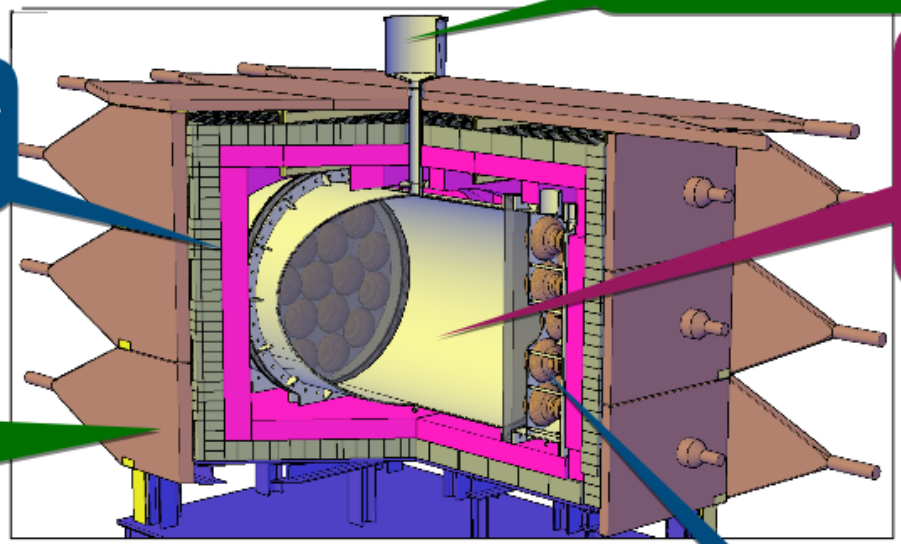


- Hanbit Reactor & Tendon Gallery



NEOS Detector

- NEOS Phase-I & II have same detector structure.



Chimney
For source calibration

Passive Shieldings
10 cm thick B-PE (n^0)
10 cm thick Pb (γ)

Active target
Homogeneous
1 kL volume
0.48% Gd-LS
Mixed LS
(LAB + UG-F)

Muon Counters
3 or 5 cm thick
plastic scintillators
(w/ two PMTs/scint.)
15 muon counters
except bottom
(9 with 2'' PMTs)
(6 with 5'' PMTs)

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

DAQ Systems
500 MHz Flash ADC for target
(recording waveforms)
62.5 MHz ADC for muon counters

NEOS Collaboration

19 members from 7 institutes.

Chung-Ang University(CAU)

Institute for Basic Science(IBS)

Korea Atomic Energy Research Institute(KAERI)

Kyungpook National University(KNU)

Korea University(KU)

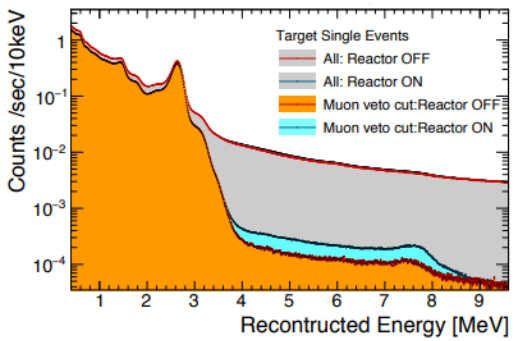
Sejong University(SJU)

Sungkyunkwan University(SKKU)

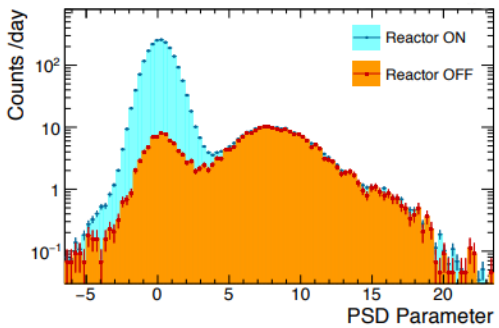
NEOS Phase-I

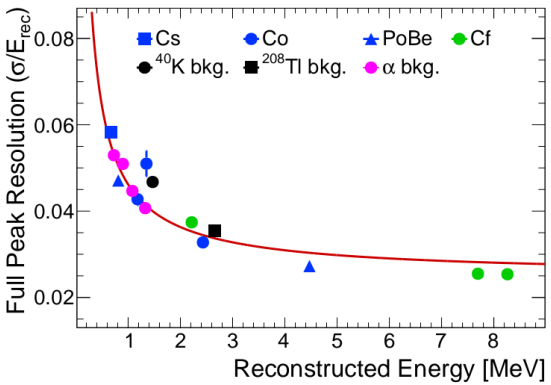
- To verify the possible existence of a eV scale sterile neutrino
- Analyzing the spectral shape (not the absolute rate) of reactor antineutrino
- Period : Sep 2015 ~ May 2016 (180/46 live days with reactor on/off)
- Energy Resolution : 5% at 1 MeV
- IBD Rate : 1977 events/day(on), 85 events/day(off) (S/B ~ 22)

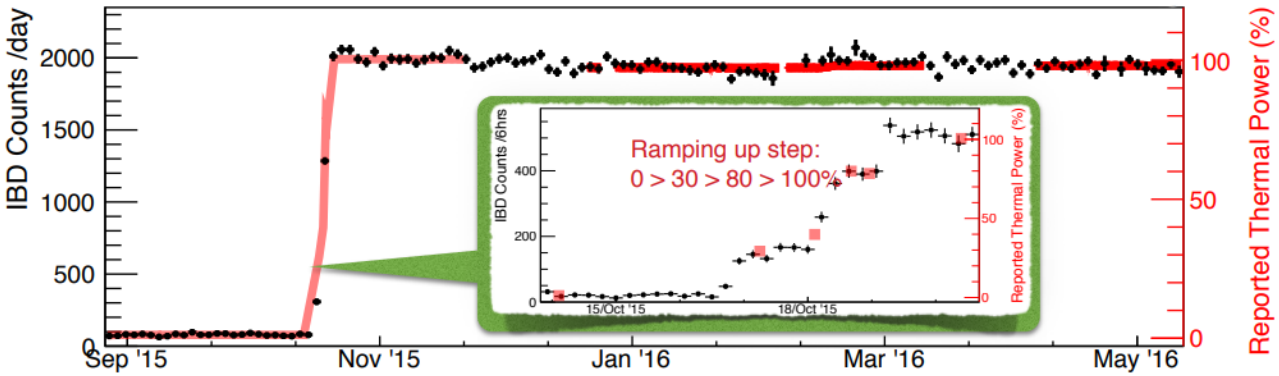
- Reconstructed Energy Spectrum

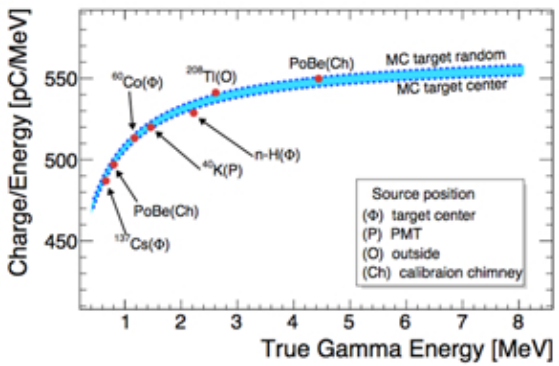


- Pulse Shape Discrimination (after muon veto)





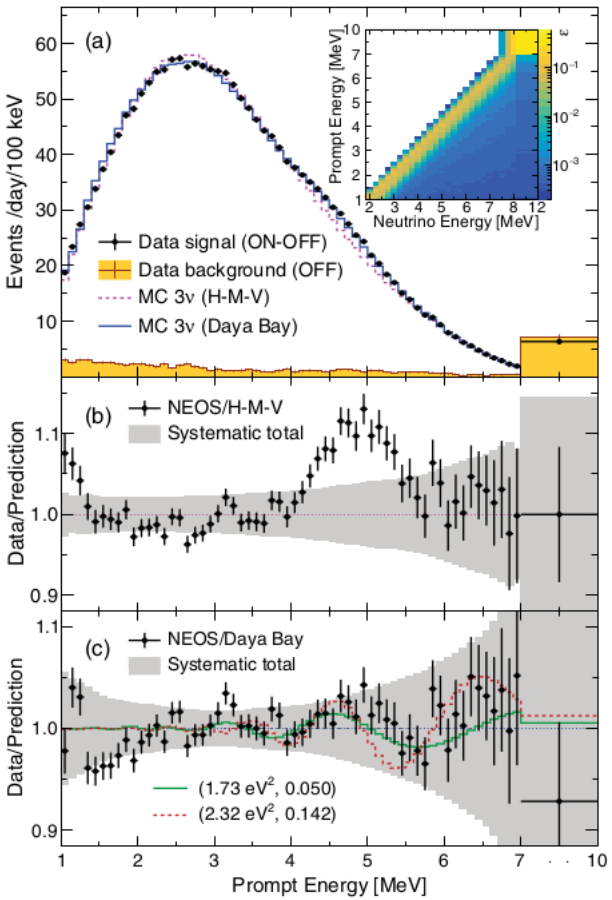




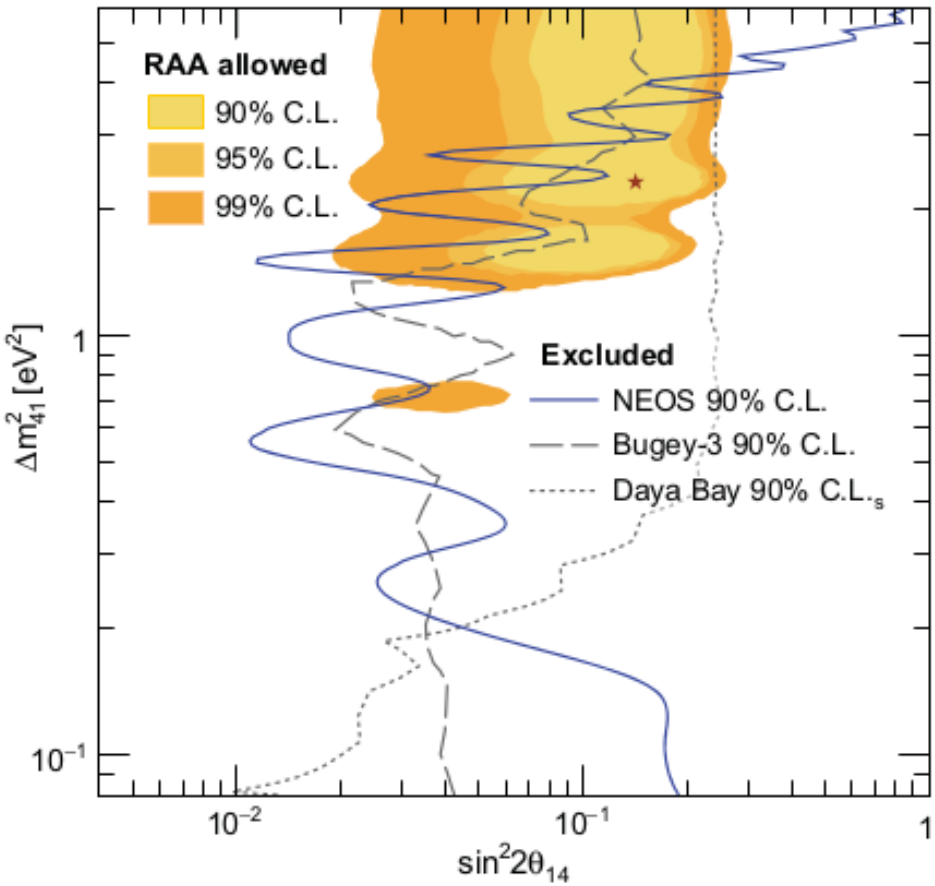
NEOS Phase-I : Results

- 5 MeV bump seen at short baseline. (NEOS Only)
- No strong sign of sterile neutrino in the detector sensitivity, from comparison with the Daya Bay spectrum.
- Phys. Rev. Lett. 118. 121802 (2017)

- Prompt Energy Spectrum & Ratio

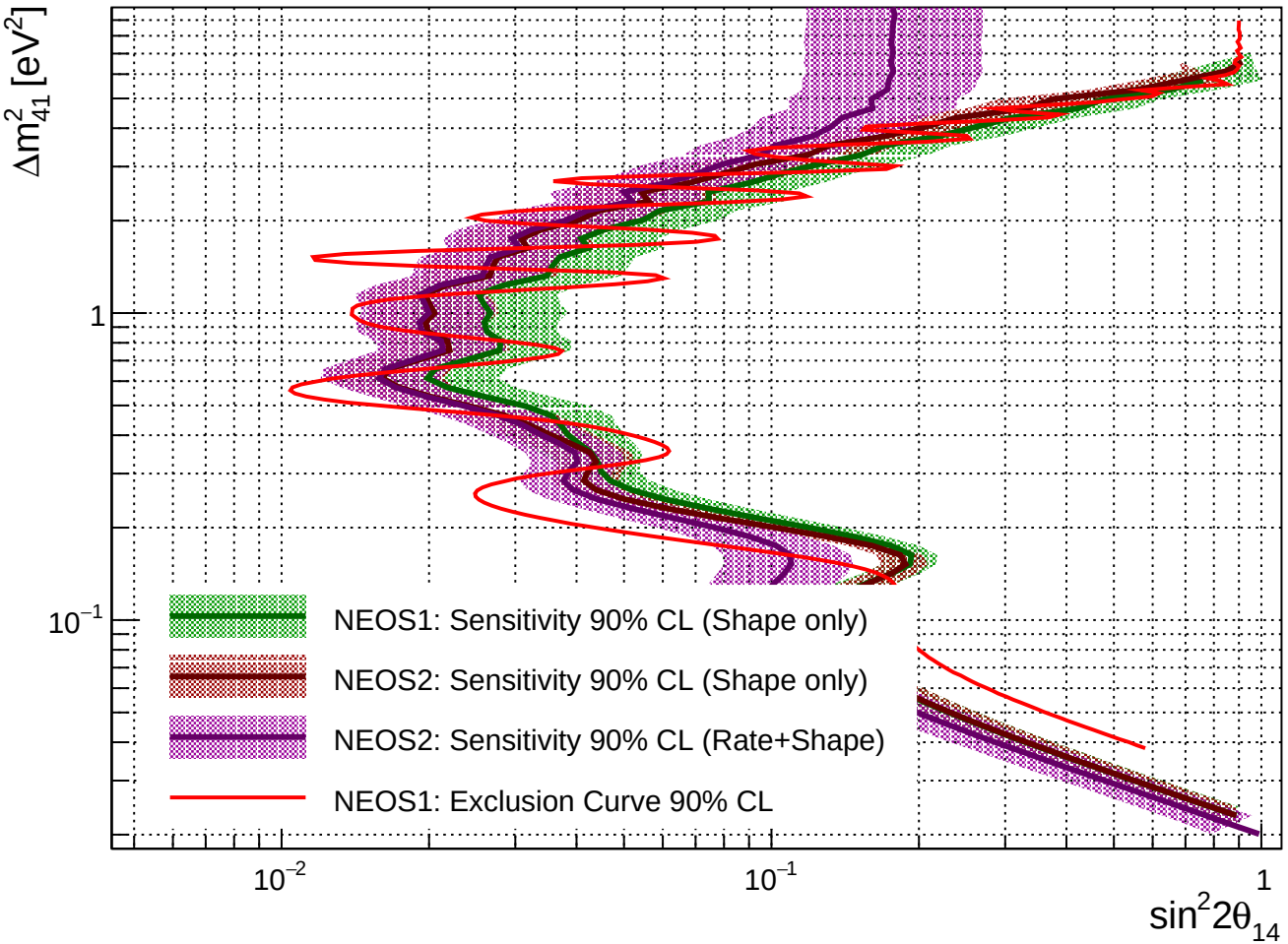


- Exclusion Curves



NEOS Phase-II : Rate + Shape

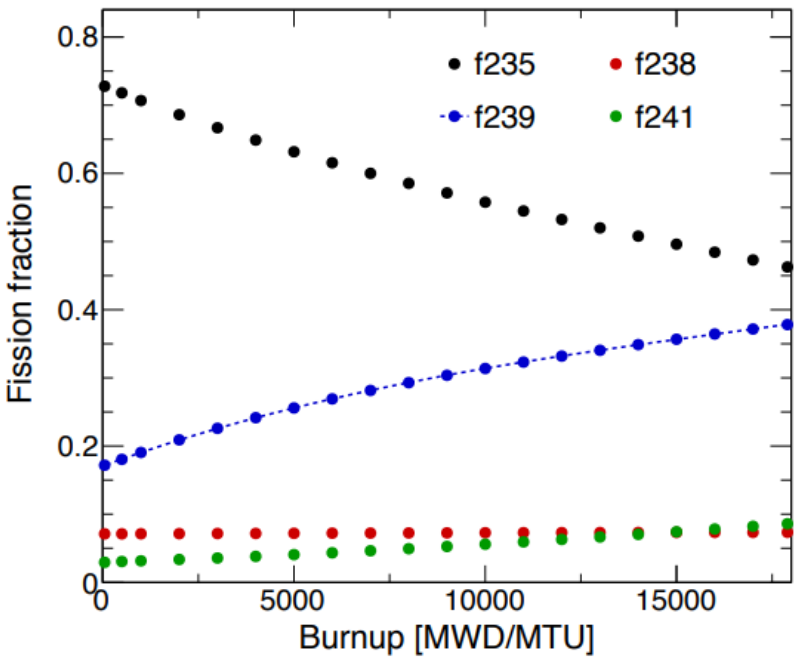
- Period : 500 days (full fuel cycle, Phase-II) vs. 180 days (Phase-I)
- Rate + shape analysis for sterile neutrino search
- Detector Sensitivity for Sterile Neutrino Search



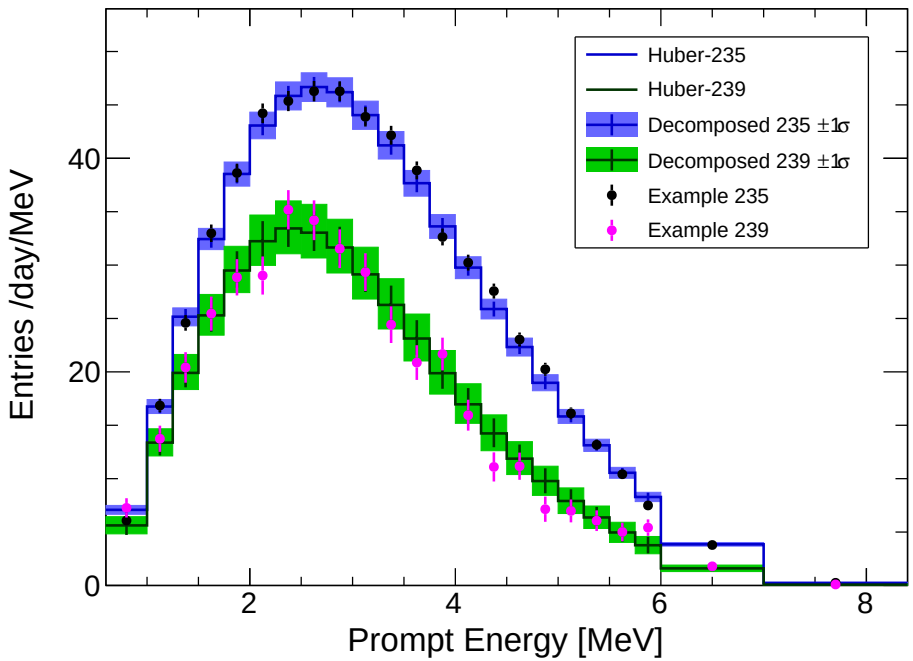
Spectrum Decomposition

- Decomposition of ν fluxes from primary fission elements
  - → Study the origin of the flux/spectral anomaly

- Fission Fractions (Real Data)

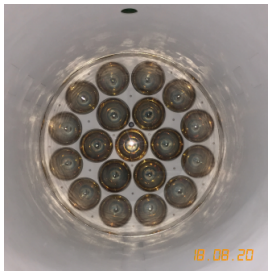


- Spectrum Decomposition (10k Toy MC)

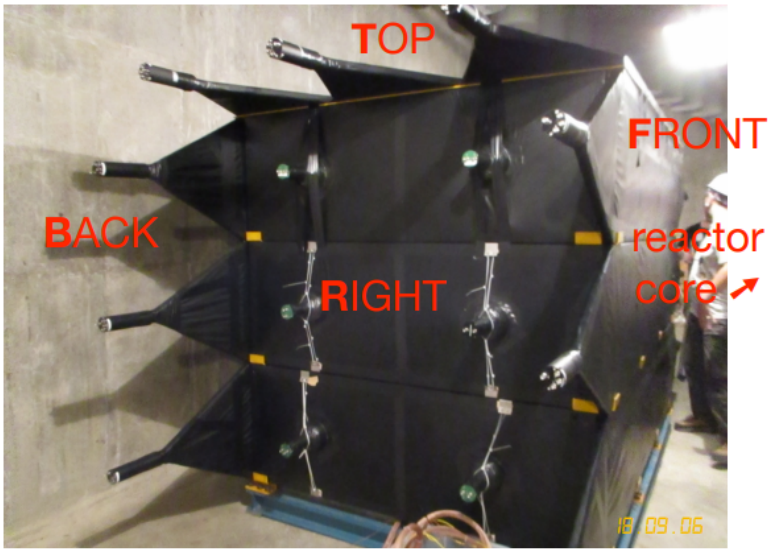


Detector Refurbishment : Phase-I → Phase-II

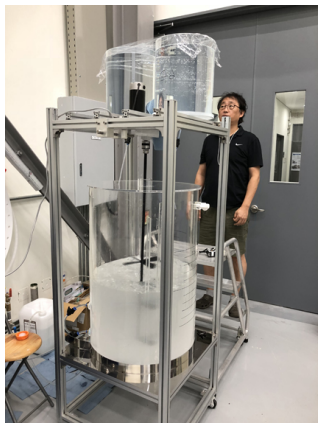
- Target



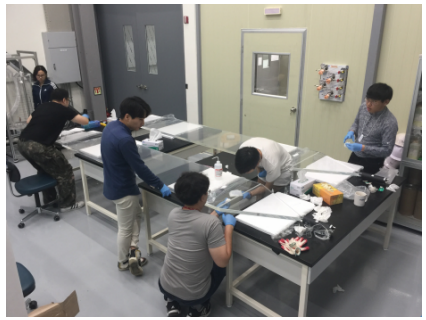
- Detector



- Gd-LS Production



- Muon Counter

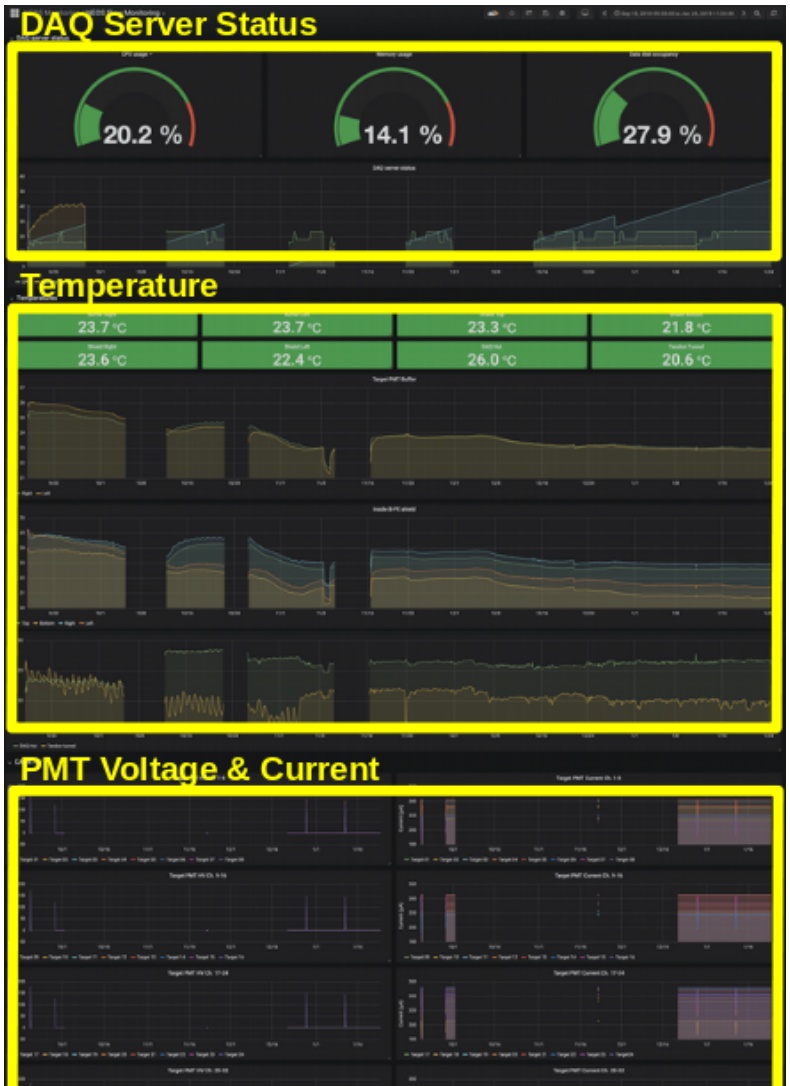


Detector Deployment (September 3 ~ 19, 2018)

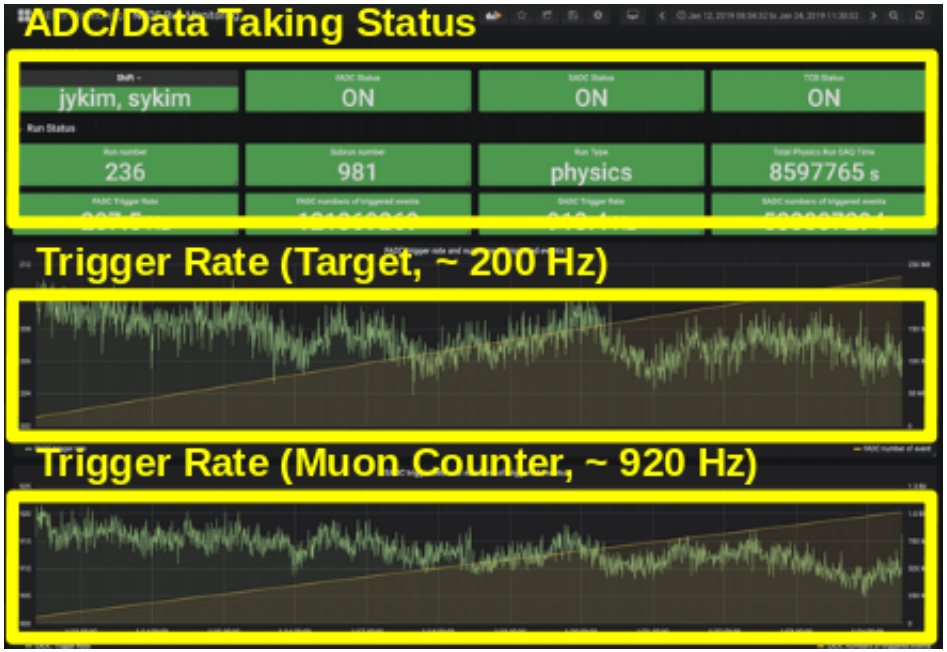
Monitoring

- Real-time monitoring for run/hardware status & radon activity

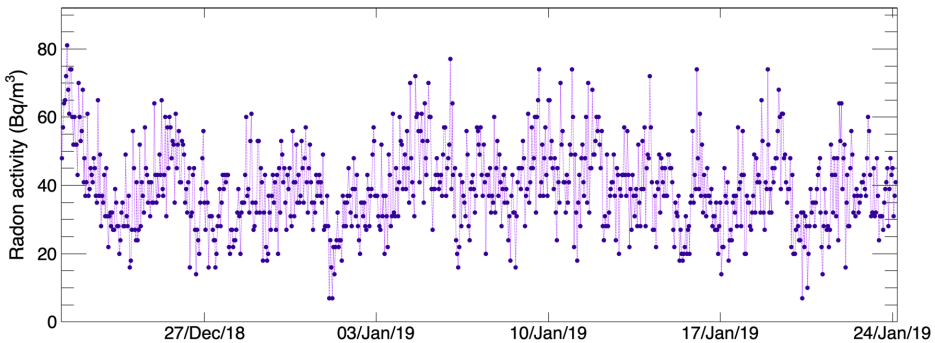
- Slow Control Monitoring



- Run Monitoring



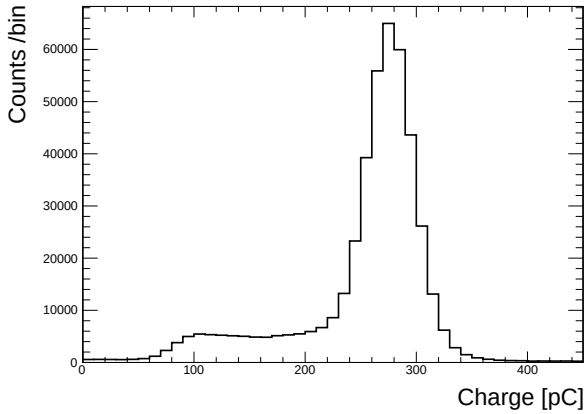
- Radon Monitoring (Radon Eye)



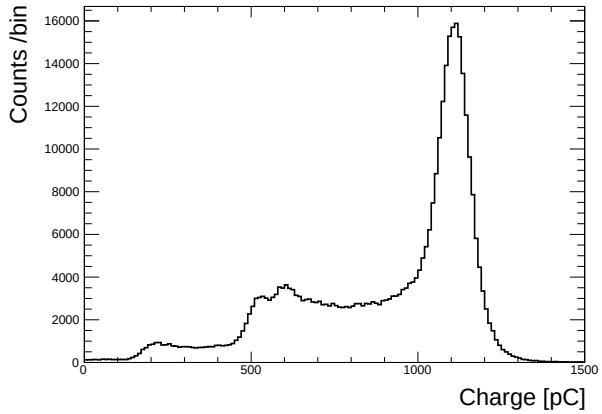
Source Calibration

- Source calibration is performed biweekly. (calibration source : ^{137}Cs, ^{60}Co, ^{22}Na, ^{252}Cf)
- Source is placed at the center of target tank.
- Plan to perform 3-D calibration soon.

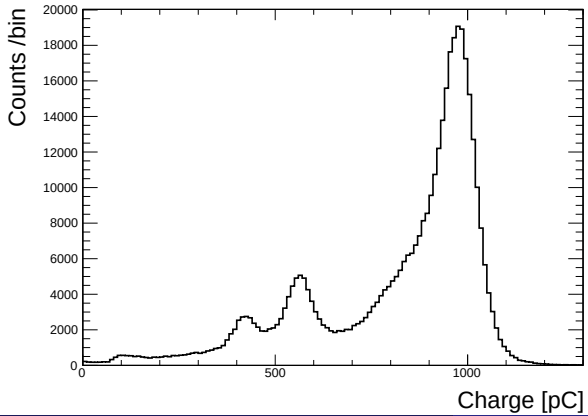
- ^{137}Cs Charge Distribution



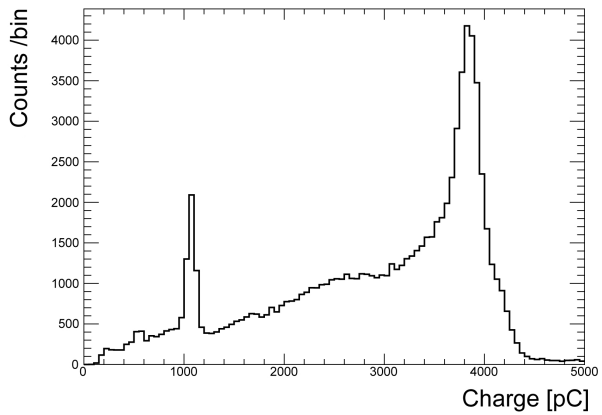
- ^{60}Co Charge Distribution



- ^{22}Na Charge Distribution

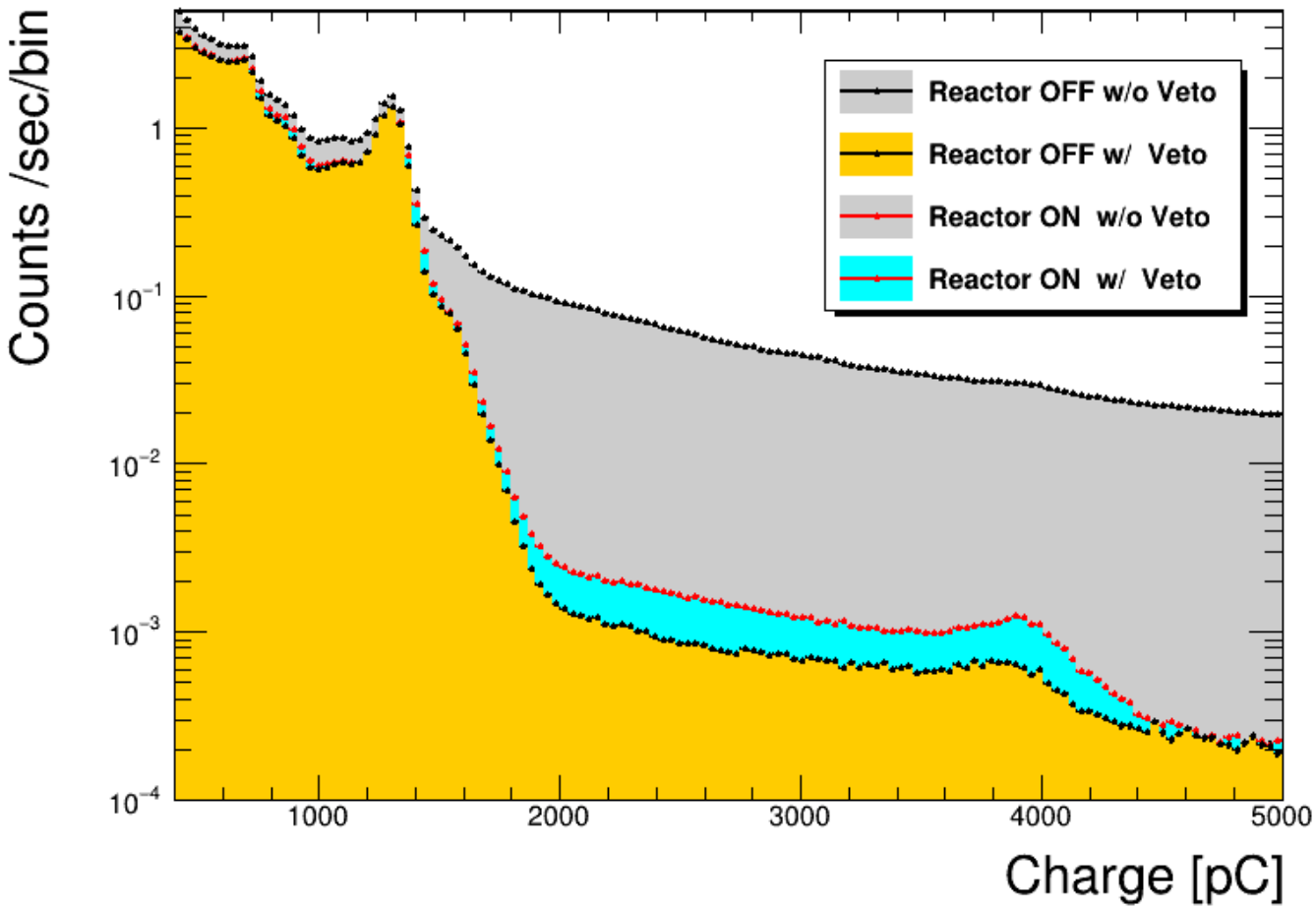


- ^{252}Cf Charge Distribution



Single Events in Phase-II Data

- No notable difference for the number of single events between reactor on and off.
- ~ 71% of single events are survived after muon veto cut was applied.
- Muon Rate : ~ 260 Hz
- Single Event Charge Distribution



Reactor Anti-neutrino Measurement

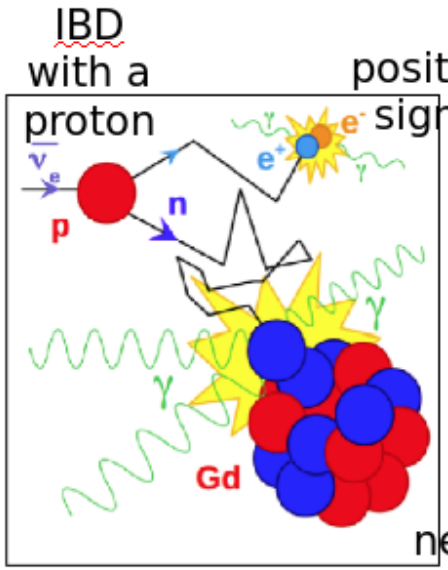
- Neutrino source: β-decay in the reactor core

  $$n \rightarrow p + e^{-} + \bar{\nu}_e$$

- Neutrino detection: Inverse beta decay (IBD) in the active target

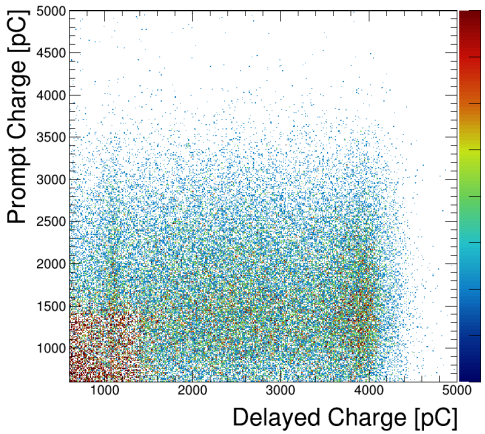
  $$\bar{\nu}_e + p \rightarrow n + e^{+}$$

- IBD in the Gd loaded liquid scintillator (Gd-LS)

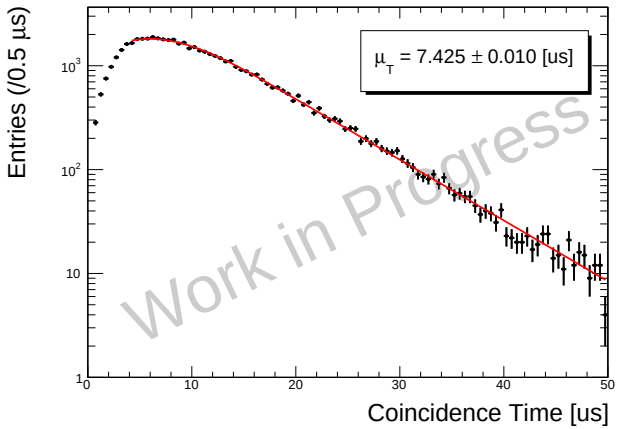


IBD Candidate (Roughly) in Phase-II Data

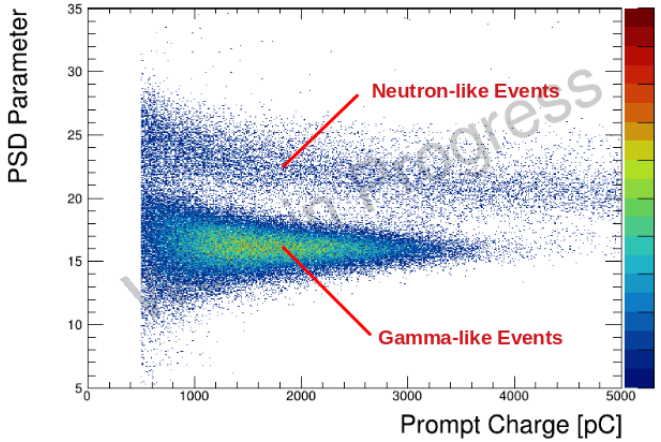
- IBD cut : muon veto, charge, multiplicity, PSD
- Charge Distributions



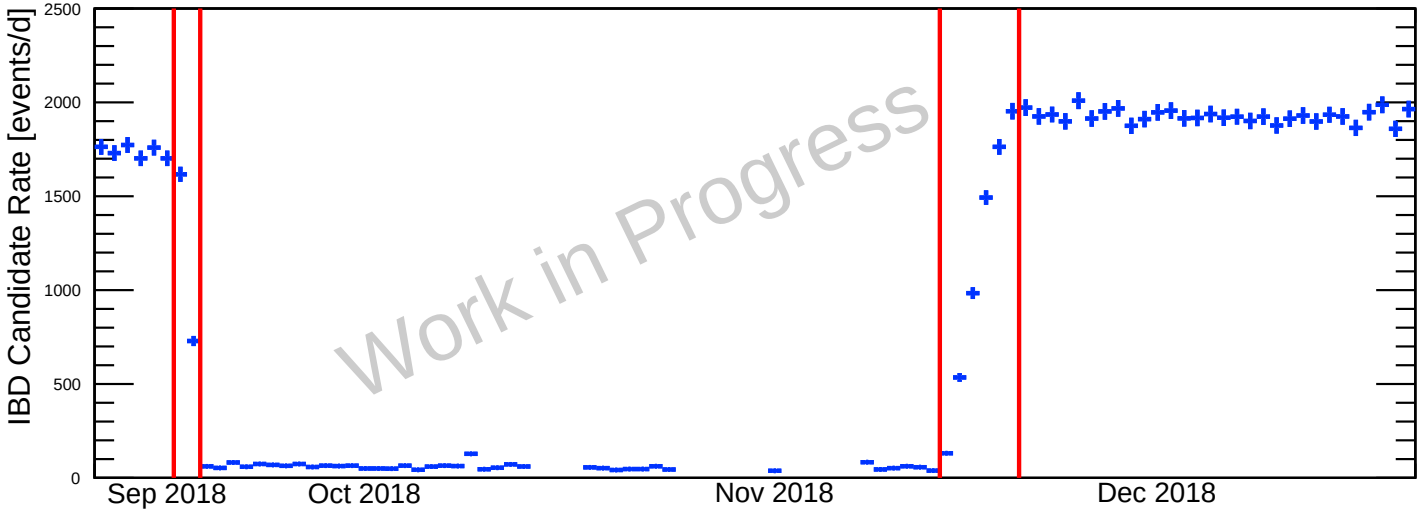
- Coincidence Time



- Pulse Shape Discrimination

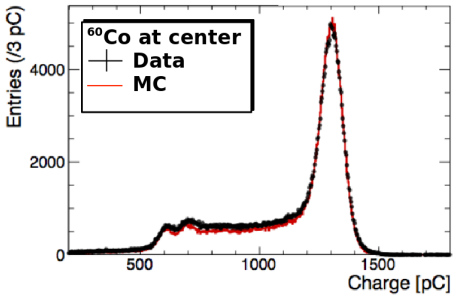


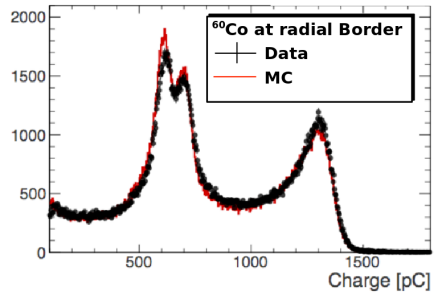
- IBD Candidate Rate (Period : Sep 2018 ~ Dec 2018)

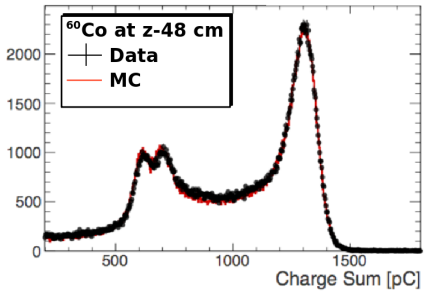


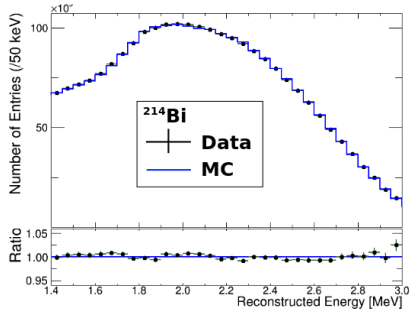
Simulation

- NEOS Simulation is based on Geant 4
- MC describes data well in NEOS phase-I



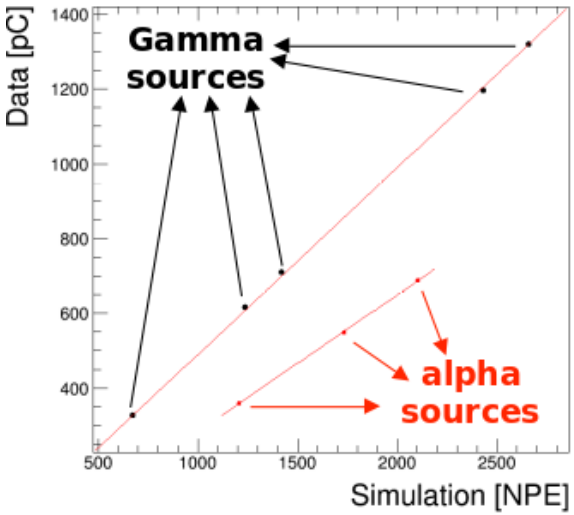




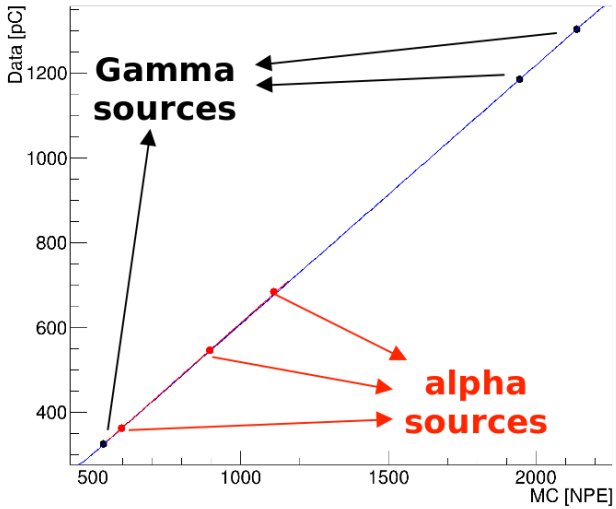


- Upgrade of MC for NEOS phase-II → will be ready soon
  - α and γ can be explained at the same time via 2nd order Birks formula
  - Phase-I data is used for study. (phase-II will be tuned.)

- Birks Formula 1st order (Phase-I)



- Birks Formula 2nd order (Phase-II)



Summary

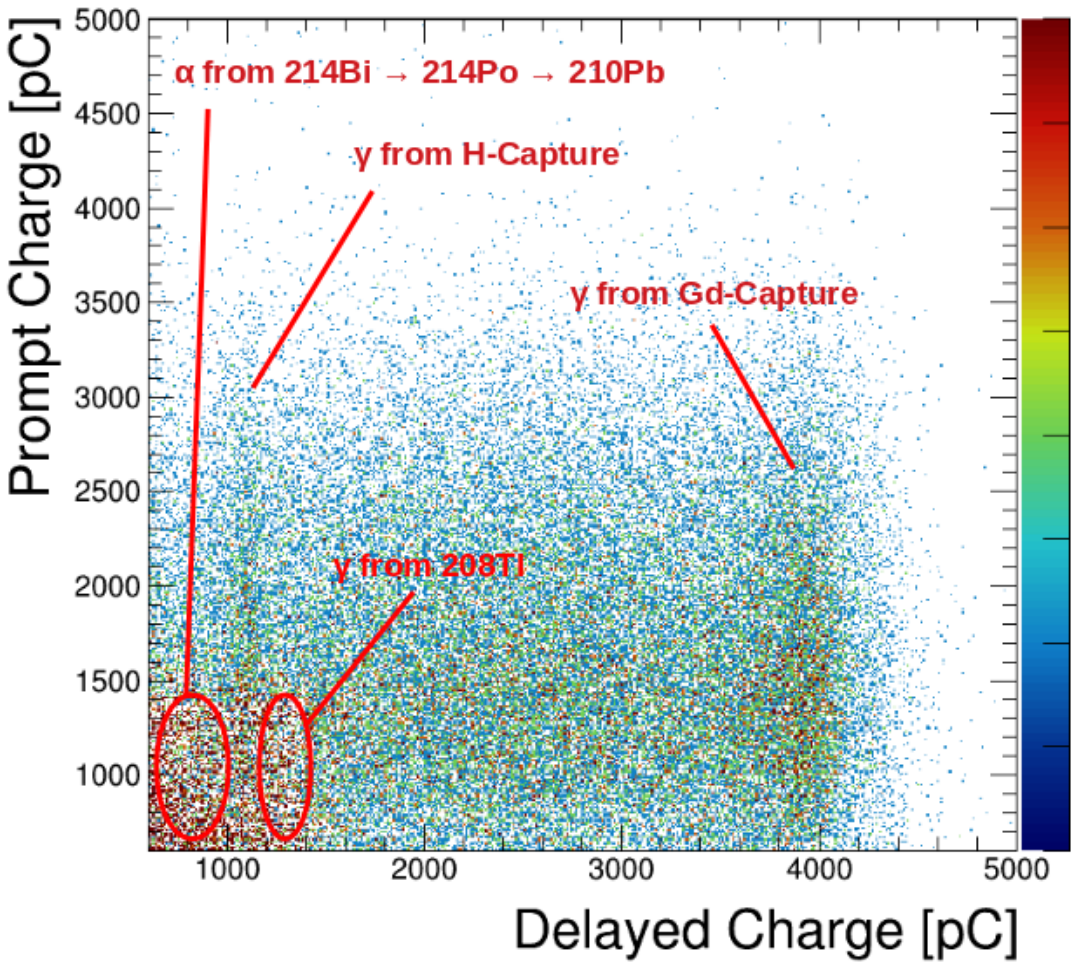
- NEOS : "Neutrino Experiment for Oscillation at Short baseline."
  - Location : Tendon Gallery of Reactor Unit 5, Hanbit Nuclear Power Plant, Yeonggwang, Korea
  - Baseline : ~23.7 m from reactor core
  - Homogeneous, 1 ton of Gd-LS active target
- NEOS phase-I was completed in Sep 2015 ~ May 2016
  - 180 live days reactor ON data.
  - 5 MeV bump seen at this short baseline.
  - No strong sign of sterile neutrino in the detector sensitivity.
  - Phys. Rev. Lett. 118. 121802 (2017)
- NEOS phase-II is ongoing from Sep 2018
  - Rate + Shape Analysis & Spectrum Decomposition
  - Plan to collect 500 live days data (full fuel cycle + 2 reactor off period(~40 days each))
  - Refurbished detector from phase-I is deployed
  - Data taking is going smoothly

Thank You!

Backup Slides

IBD Candidate Charge Distribution

- ^{214}Bi → ^{214}Po : Beta Decay / ^{214}Po → ^{214}Pb : Alpha Decay (contaminated by air)
- ^{208}Tl → ^{208}Pb : Beta Decay → Gamma Decay (from borated PE)



Significance Test

- 0.3M sets of pseudo-experiments for significance test
- There is no strong evidence of light sterile neutrino with 3+1 hypothesis.

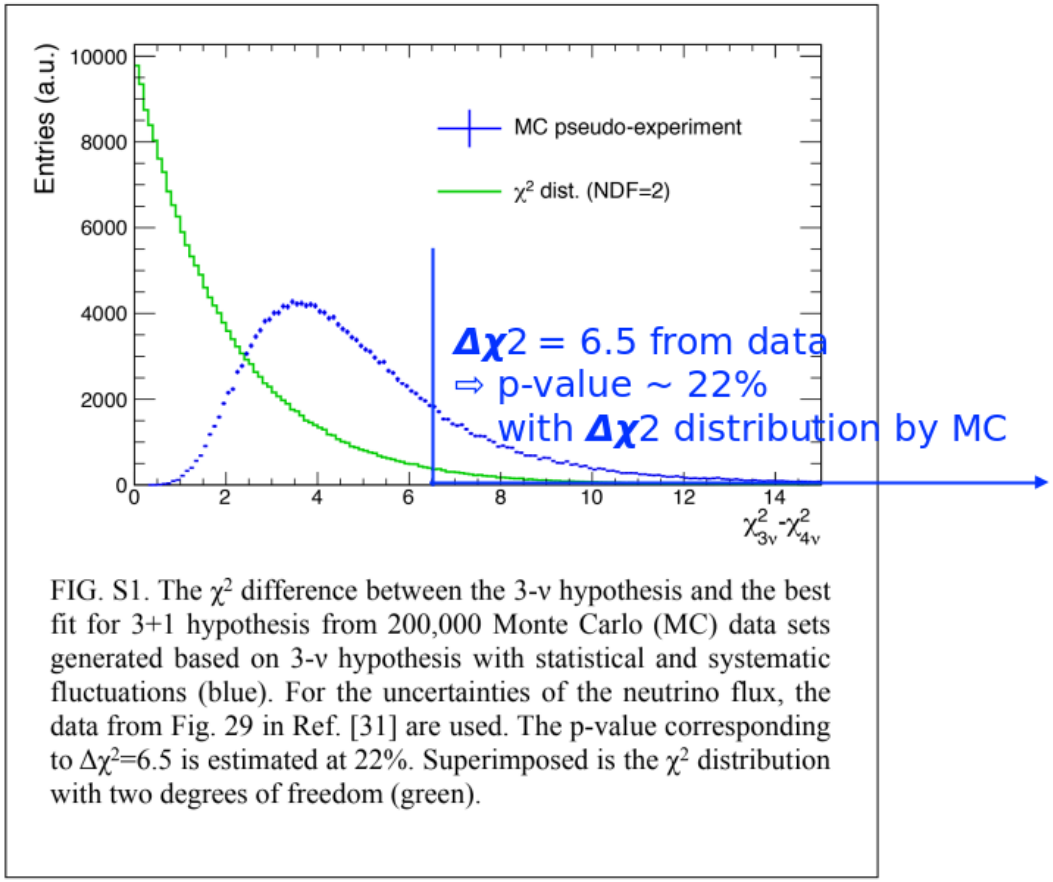


FIG. S1. The χ^2 difference between the 3-ν hypothesis and the best fit for 3+1 hypothesis from 200,000 Monte Carlo (MC) data sets generated based on 3-ν hypothesis with statistical and systematic fluctuations (blue). For the uncertainties of the neutrino flux, the data from Fig. 29 in Ref. [31] are used. The p-value corresponding to $\Delta\chi^2$=6.5 is estimated at 22%. Superimposed is the χ^2 distribution with two degrees of freedom (green).