

A Neutrino Telescope Project at Yemilab :

ν EYE (new eye, ν eutrino Experiment at YEmilab)

CPNR Workshop 2025: Neutrino and Physics Beyond Standard Model
Oct. 24 - 27, 2025
Chonnam National University

Eunil Won
Korea University, Oct. 24, 2025

ν EYE web: <http://nueye.korea.ac.kr>

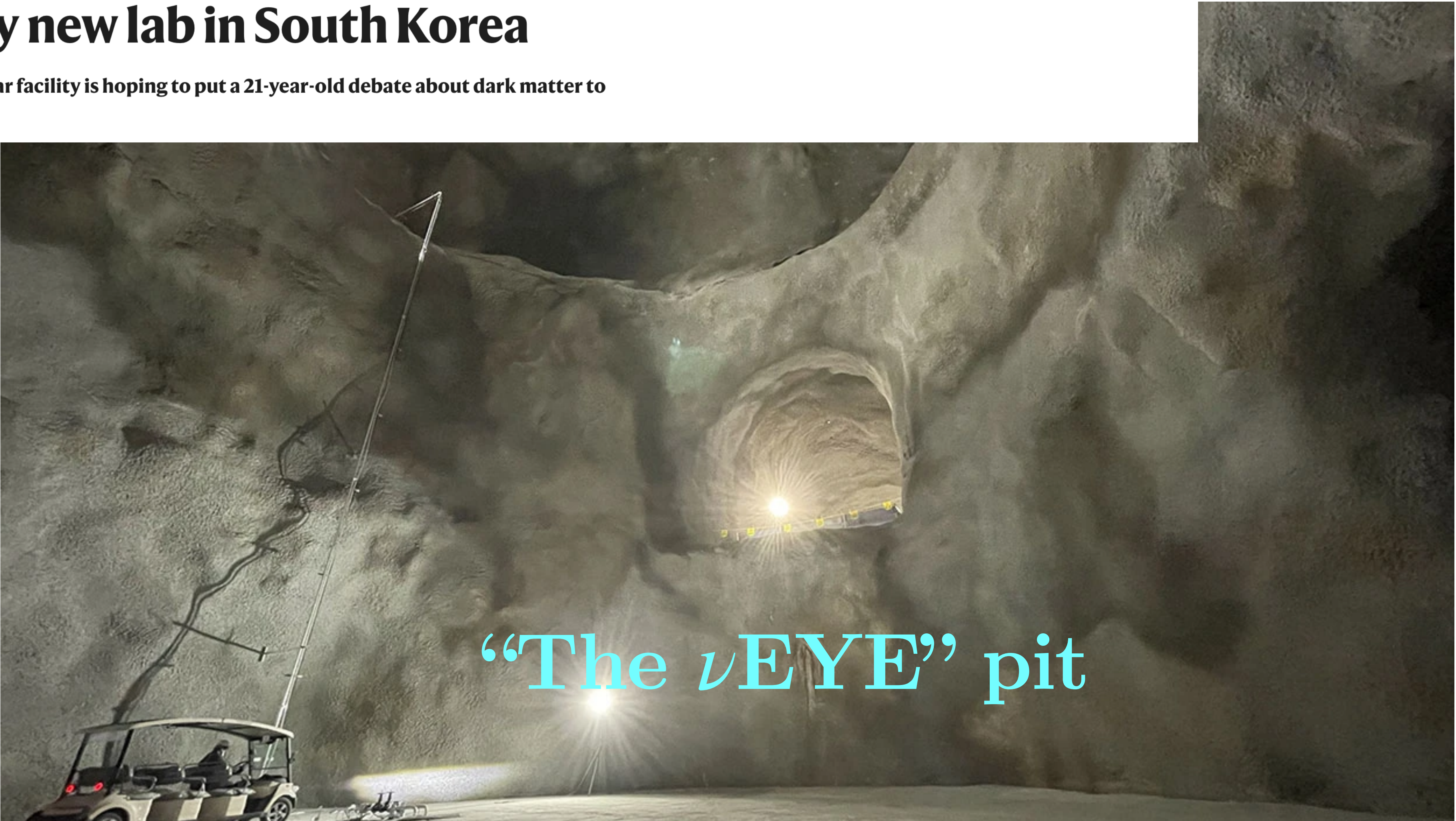
Yemilab

Disputed dark-matter claim to be tested by new lab in South Korea

A multi-million dollar facility is hoping to put a 21-year-old debate about dark matter to rest.

A new underground facility in Korea (1000 m deep).
(<https://arxiv.org/abs/2402.13708>)

Yemilab “LSC center” can host $O(2)$ kilo tonne detector.



“The ν EYE” pit

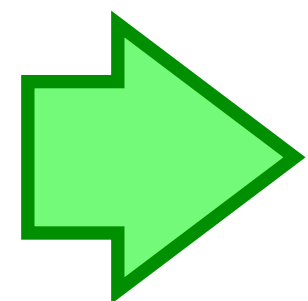
Selected Physics Cases

Summary of sterile neutrino search over the last 20 years

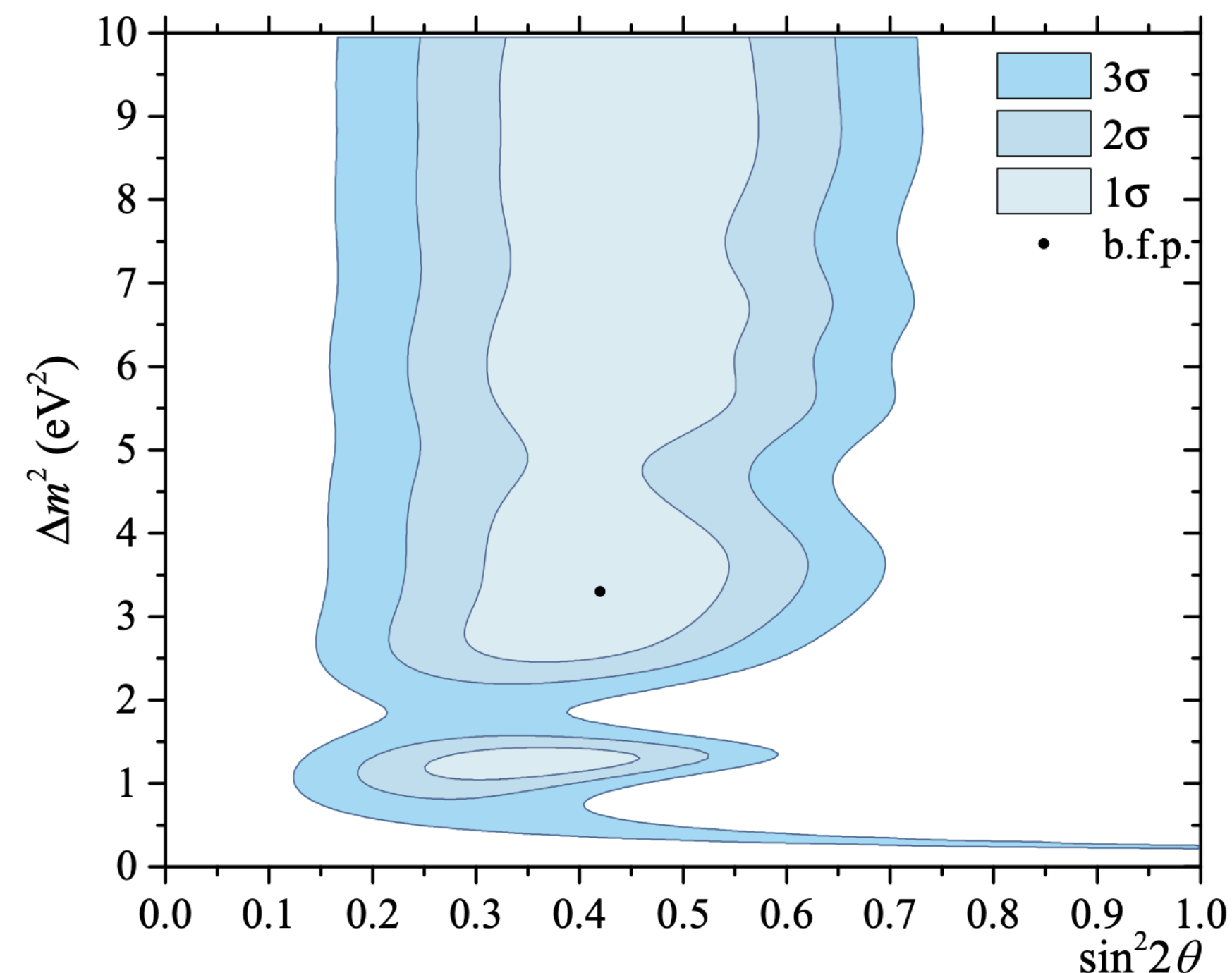
Since the LSND anomaly, a lot of efforts went into the search for the sterile neutrino.

- KARMEN (neutron spallation) did not confirm LSND.
- MiniBooNE ($\nu_e + \bar{\nu}_e$) compatible with LSND but with low energy excess.
- μ BooNE disfavors MiniBooNE and LSND (not rule out completely).
- Daya Bay, RENO found deficit but likely due to flux calculation issue.
- NEOS, STEREO, PROSPECT, DANSS, SOLID: no evidence, Neutrino4 found arguable 3σ signal ($\Delta m^2 = 7 \text{ eV}^2$).

- SAGE, GALLEX (solar ν_e disappearance) found Gallium anomaly.
- Most recently **BEST** experiment claimed 4σ signal (3.4 MCi ^{51}Cr source, radiochemical method)



Has to to be resolved.

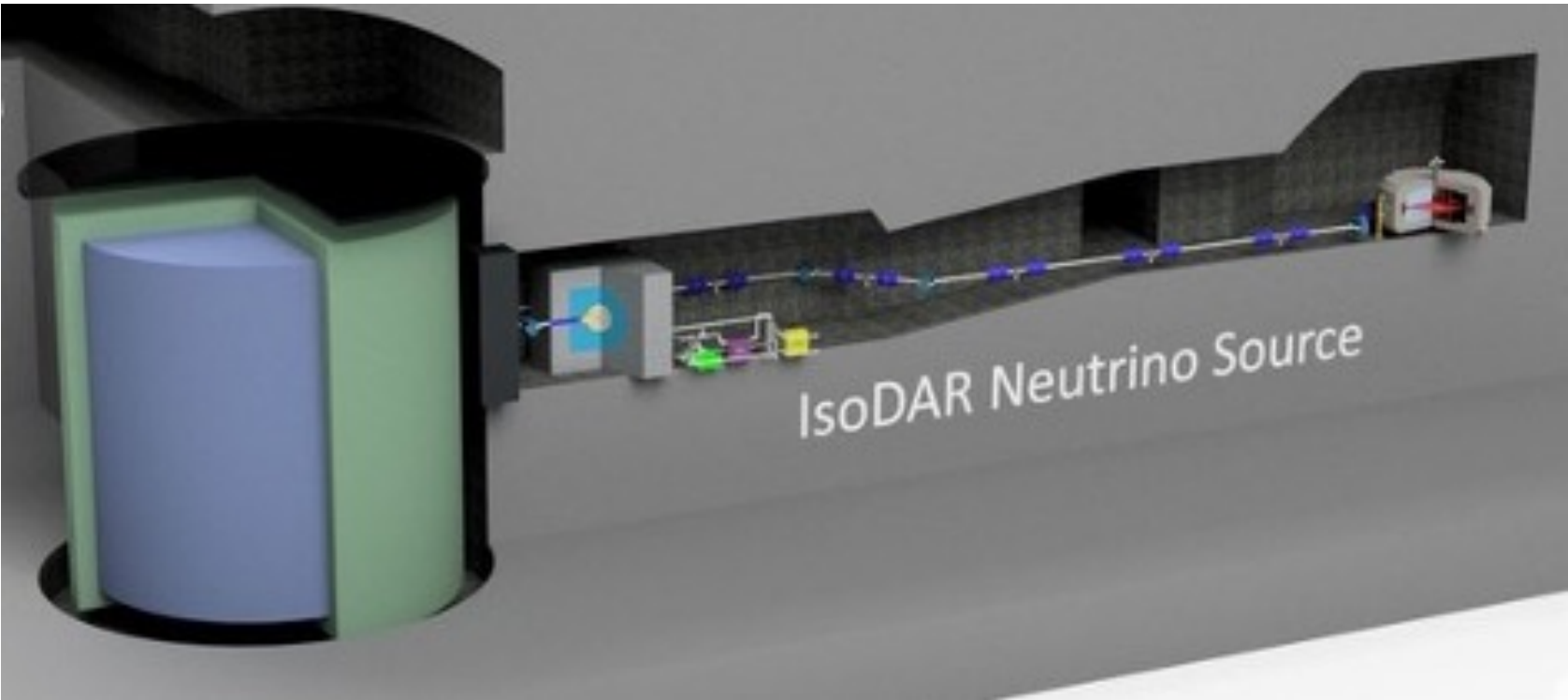


Baksan Experiment on
Sterile Transitions (BEST)

Phys. Rev. Lett. 128, 232501
(2022)

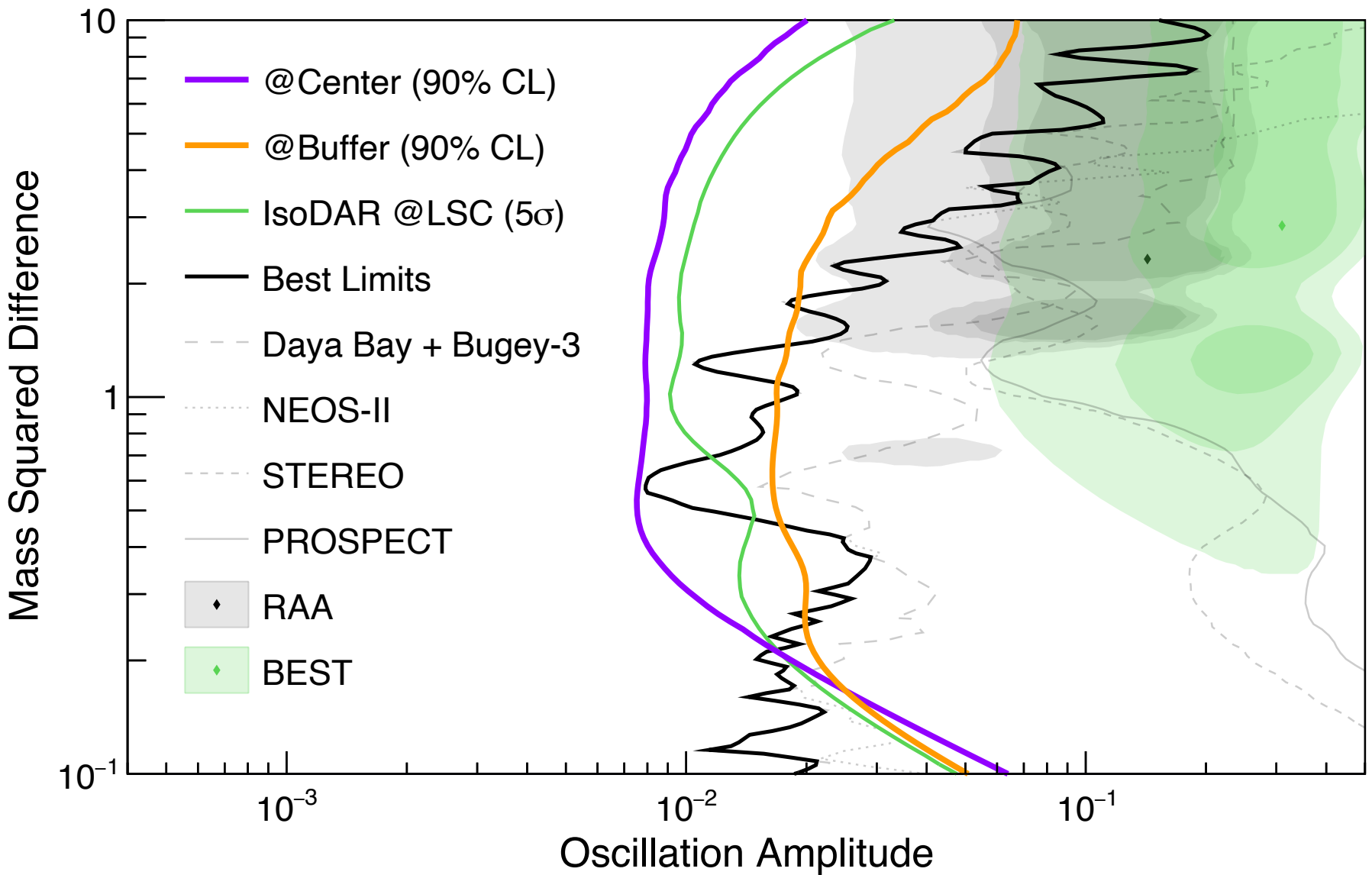
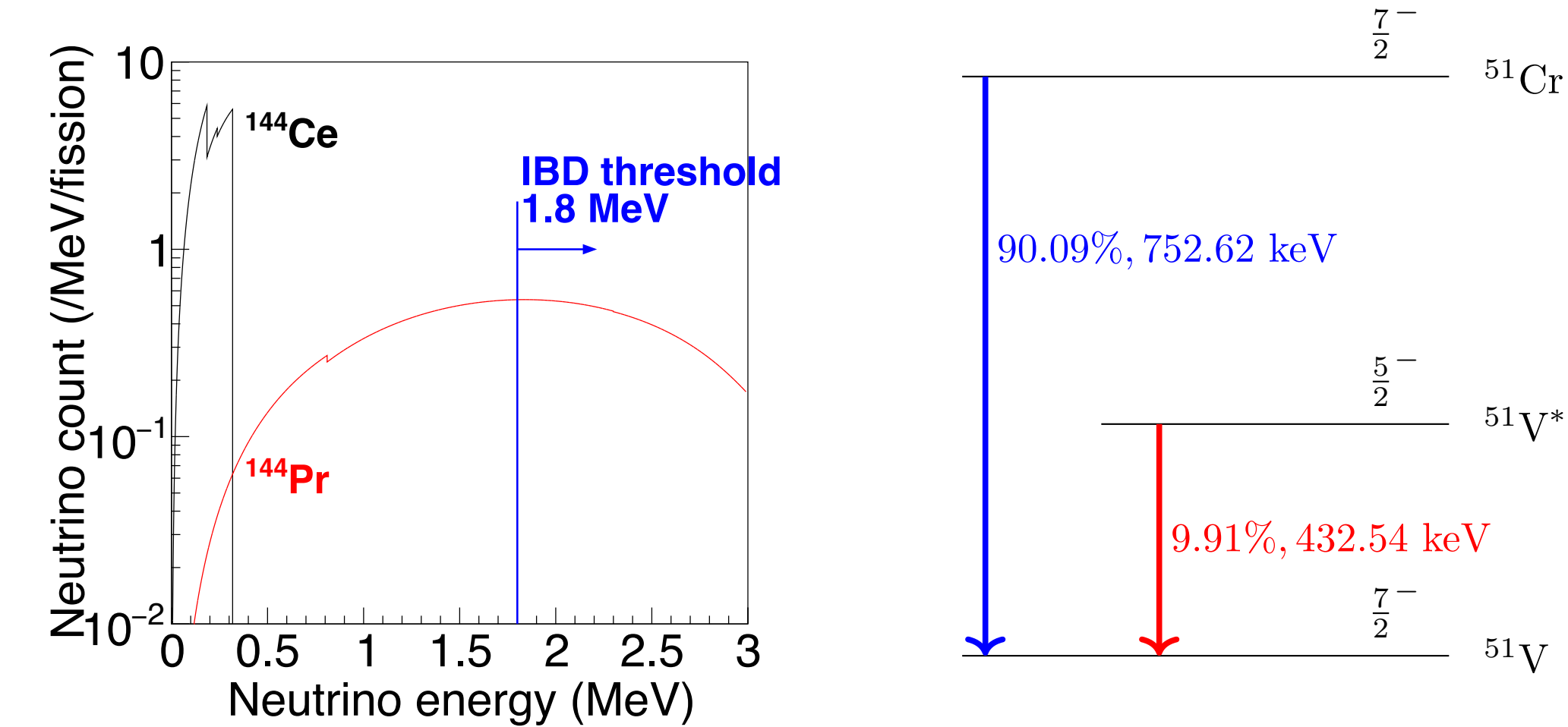
Sterile neutrino search with ν EYE

Option 1: Generation of neutrinos with high-intensity accelerator (IsoDAR).



(Isotope Decay-At-Rest)

Option 2: use high activity radioactive source + in situ detection of signal.

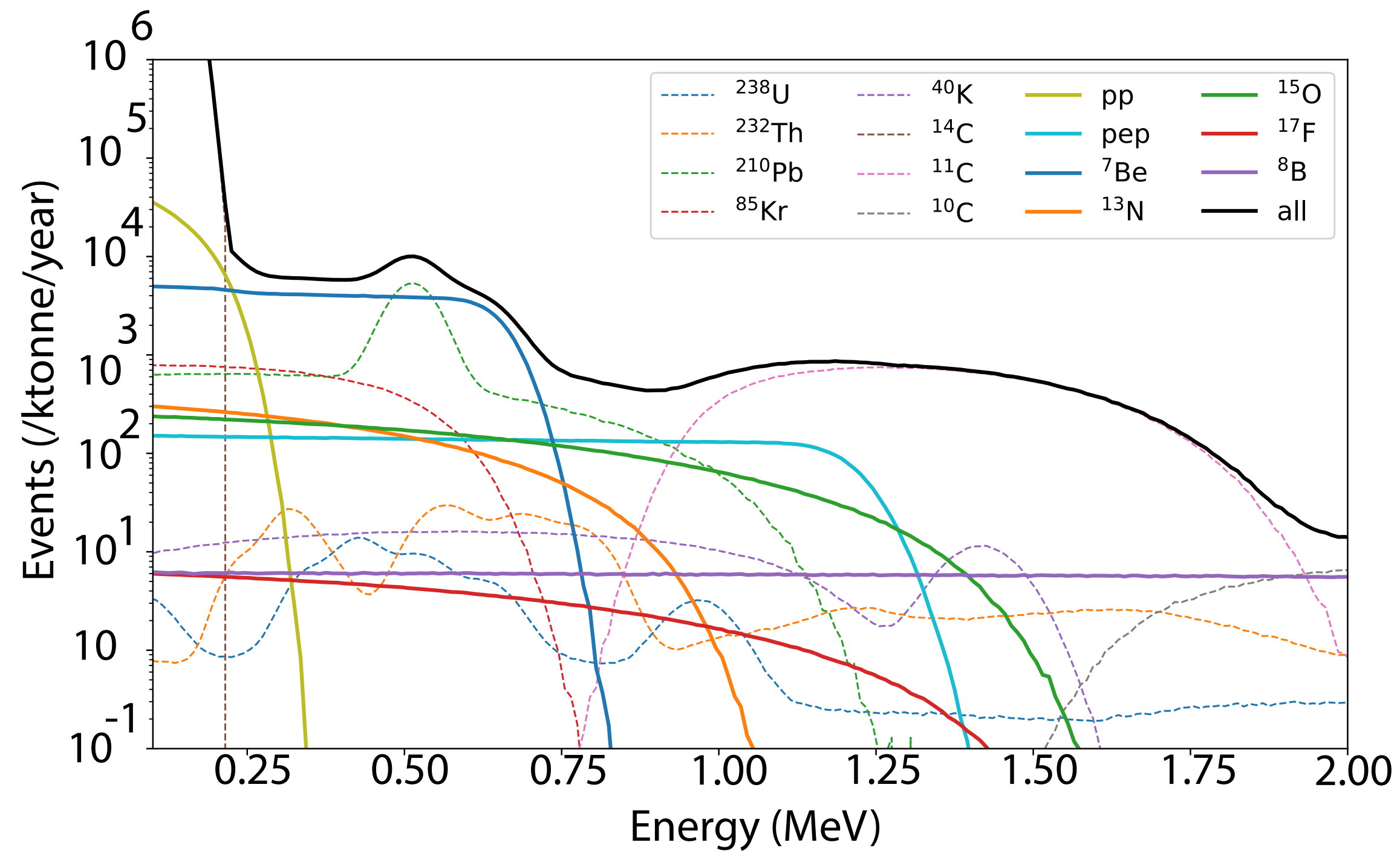


Both options allow us to confirm or rule out BEST result.

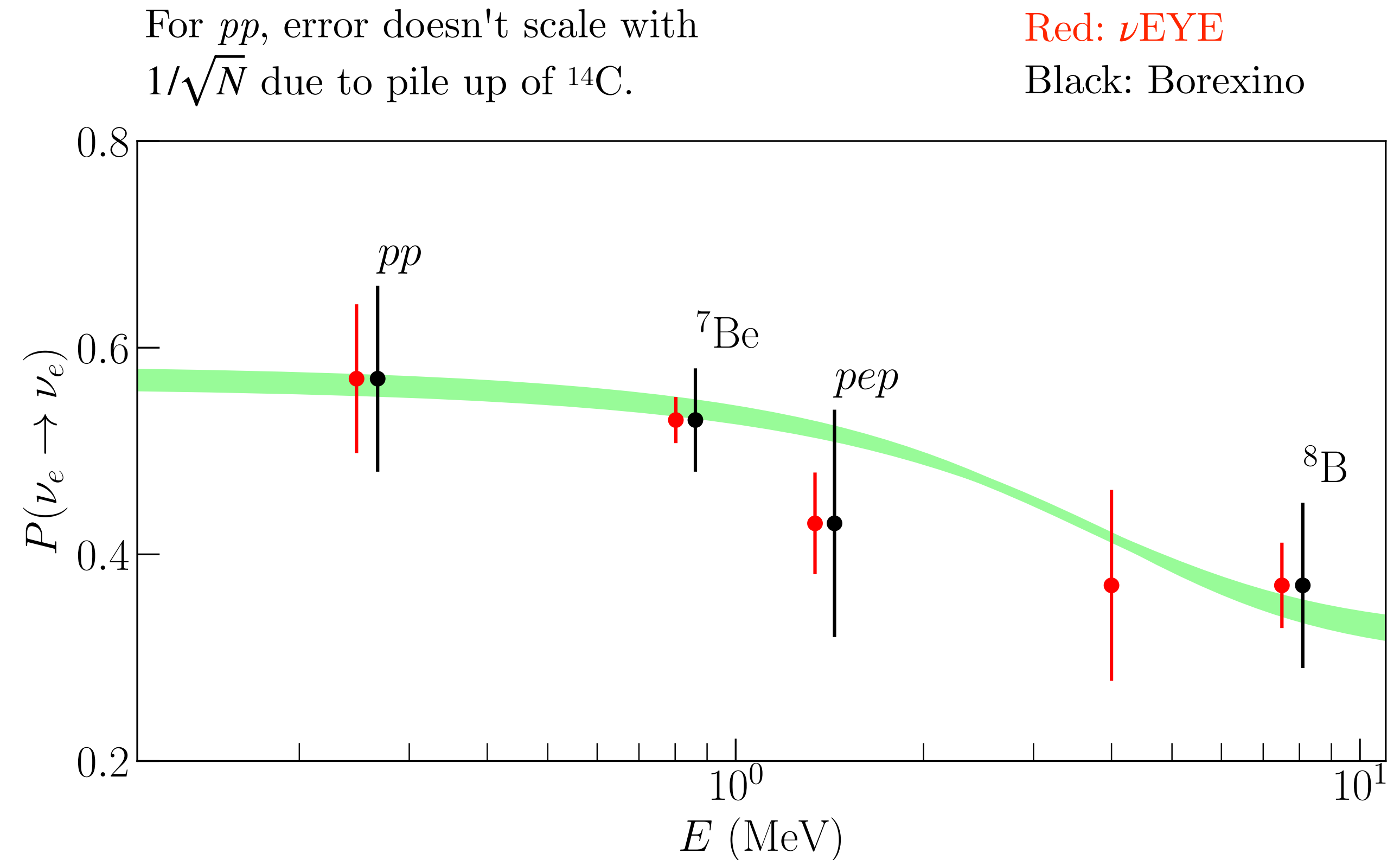
Solar neutrino physics with ν EYE

Among possible topics, so called **observation of the “up-turn”** seems the most important.

- Radio-purification is required.



Detailed understanding of signal/background (reduction of background) is critical.

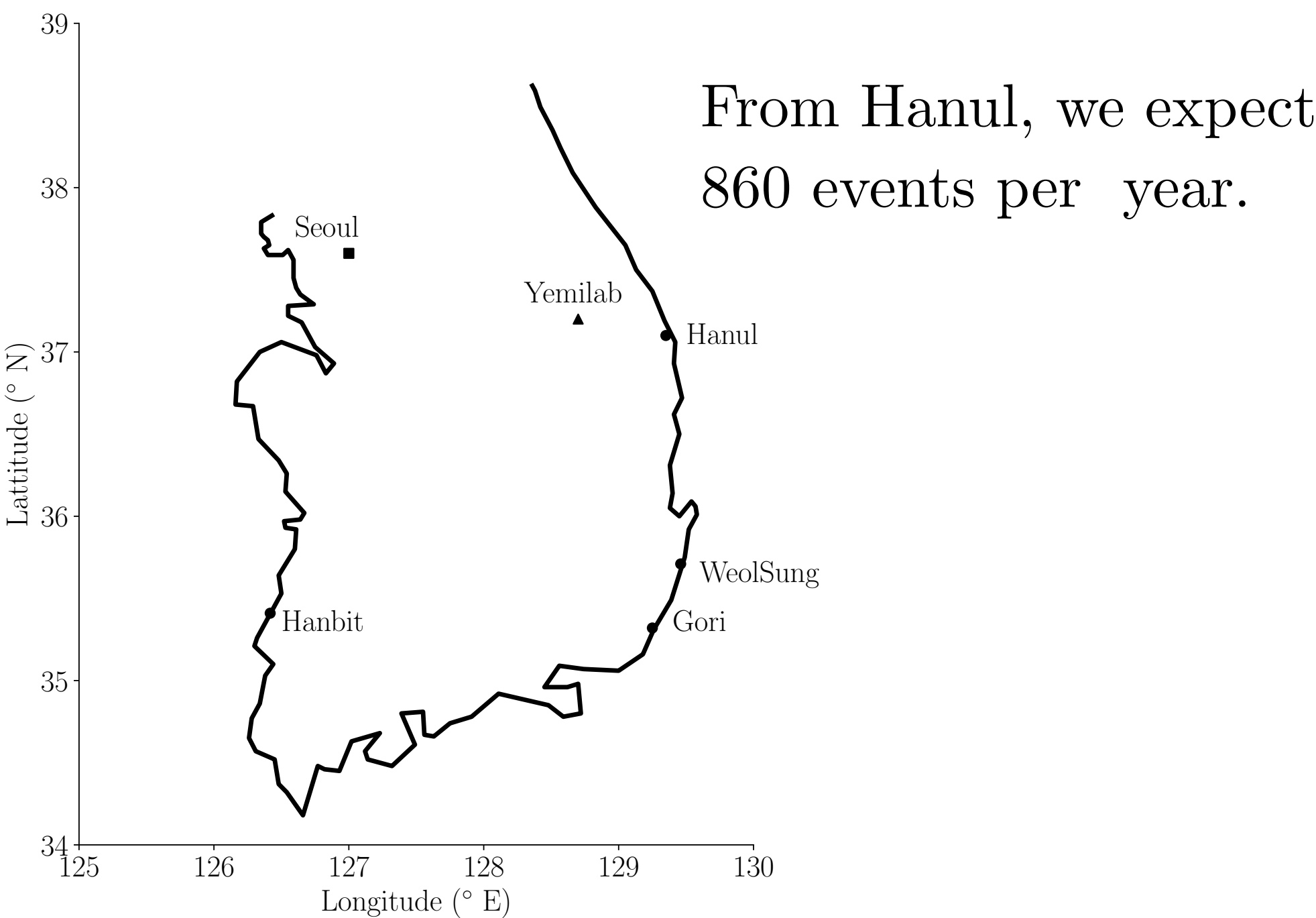


$\longleftrightarrow$

ν EYE can provide points in this region.

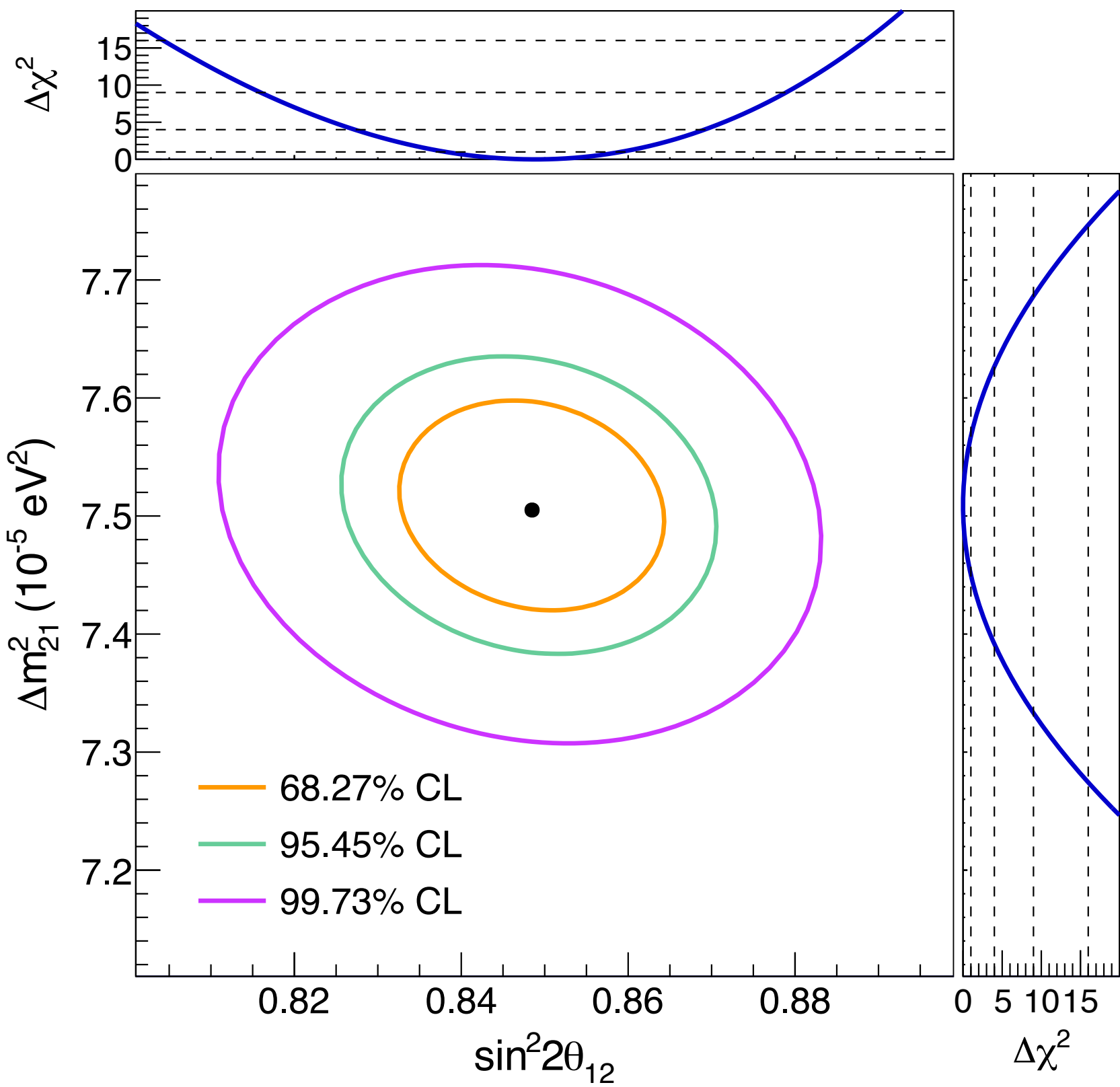
Reactor neutrino with ν EYE

The JUNO experiment will measure 3- ν oscillation parameters with high precision.
But JUNO findings **need to be validated**: the ν EYE is also at the first minimum.



	Hanul	Wolsong	Gori	Hanbit
Thermal Power (GW)	20.8	11.8	21.3	16.9
Baseline (km)	65	180	216	282

ν EYE sensitivity on Δm_{21}^2 and $\sin^2 2\theta_{12}$



$$\Delta m_{21}^2 = (7.51 \pm 0.06) \times 10^{-5} \text{ eV}^2 \text{ and } \sin^2 2\theta_{12} = 0.848 \pm 0.010 \text{ (all statistical error only)}$$

Neutrinoless double beta decay with ν EYE

At the end of the experiment, the ν EYE telescope can be loaded with metal to allow a neutrino-less double beta decay experiment.

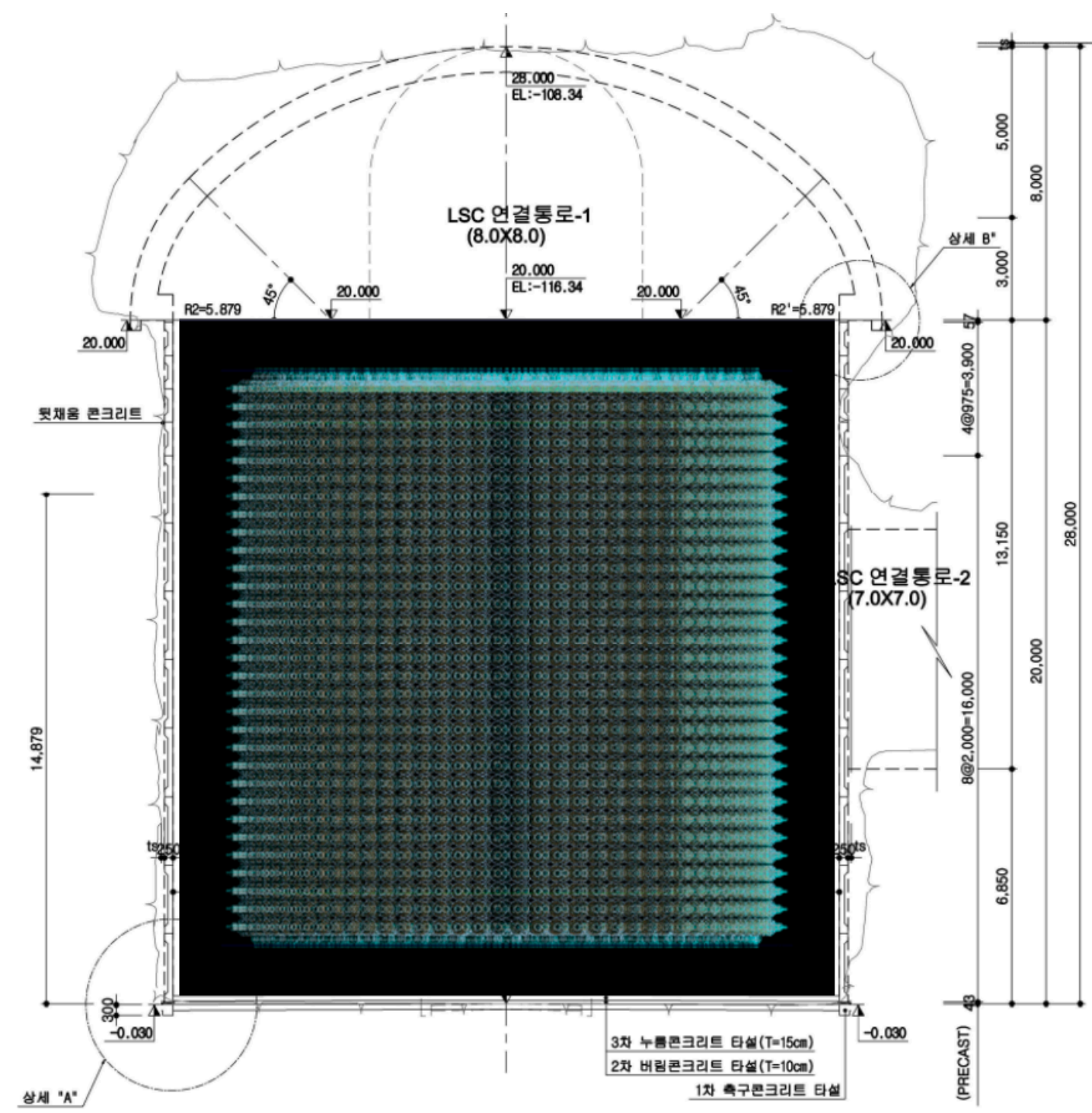
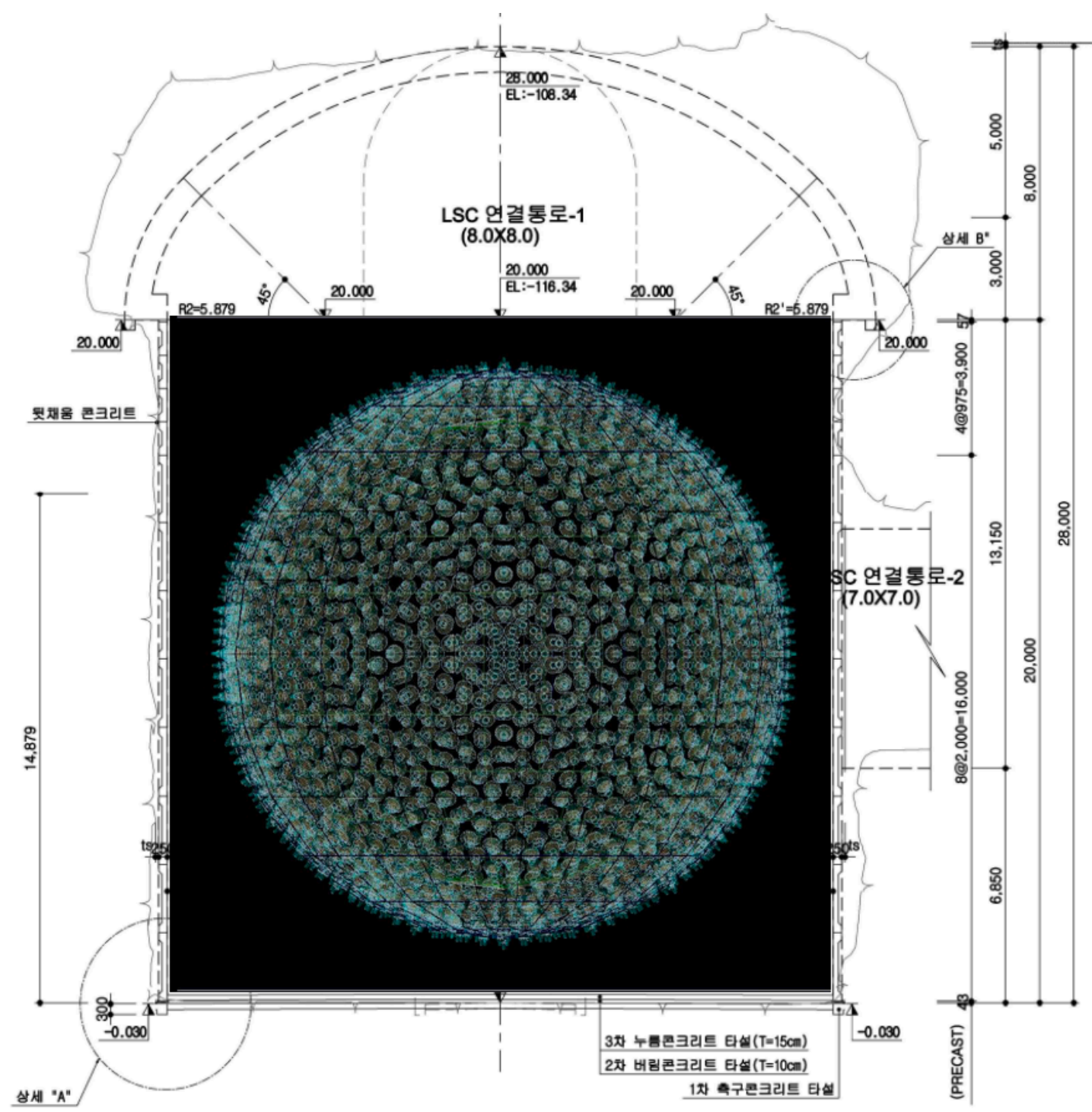
One possible candidate isotope is Tin-124 ($Q=2.2$ MeV). Another possible choice is ^{130}Te that has a $Q = 2.54$ MeV. It has relatively high natural abundance of 34.1%. Our target half-life time sensitivity is of order 10^{28} years.

This topic requires a long-term R&D on the loading issues.

Detector Design

Detector concept

A 2 kilo tonne liquid scintillator (the actual target-mass is smaller).
At this moment, we consider two options: **spherical** or **cylindrical**.

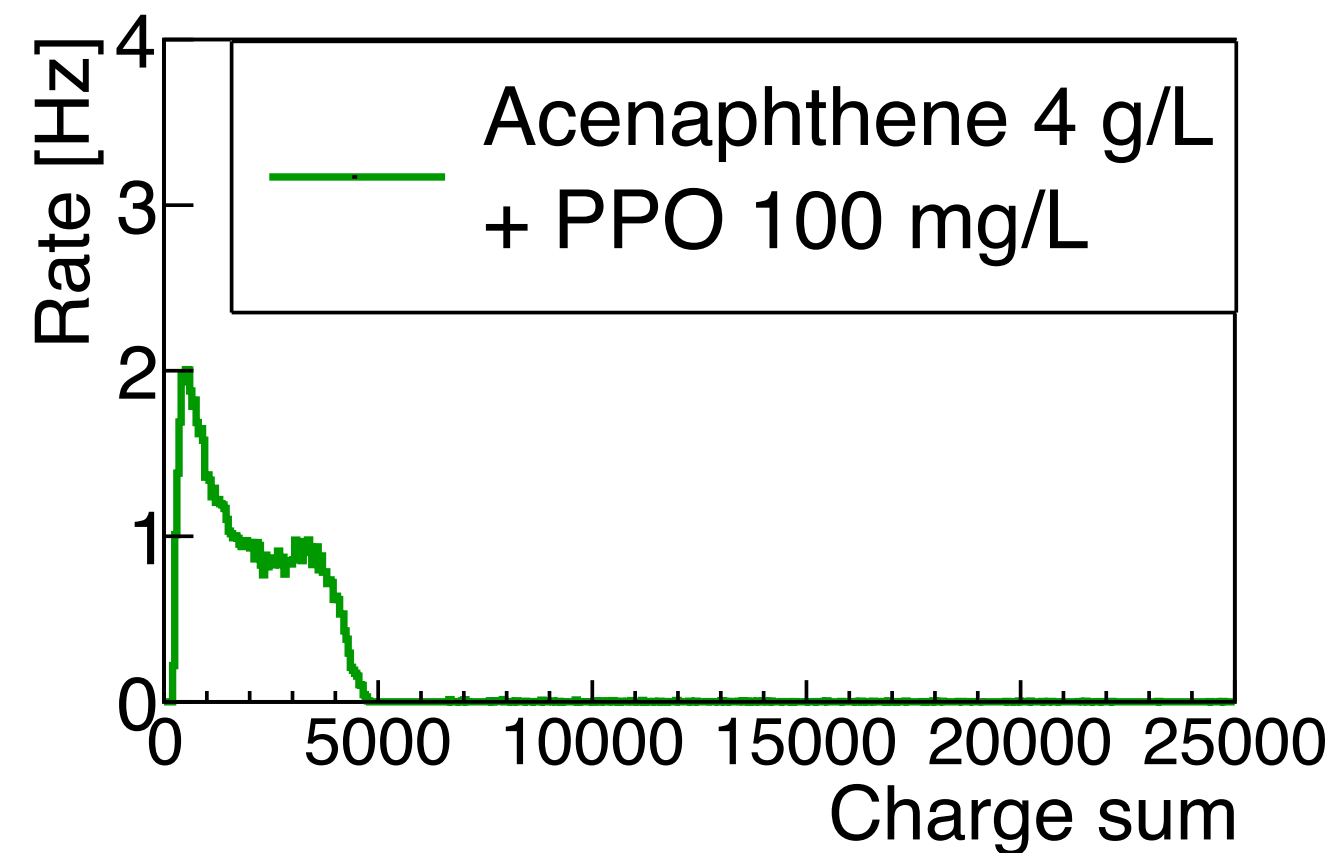
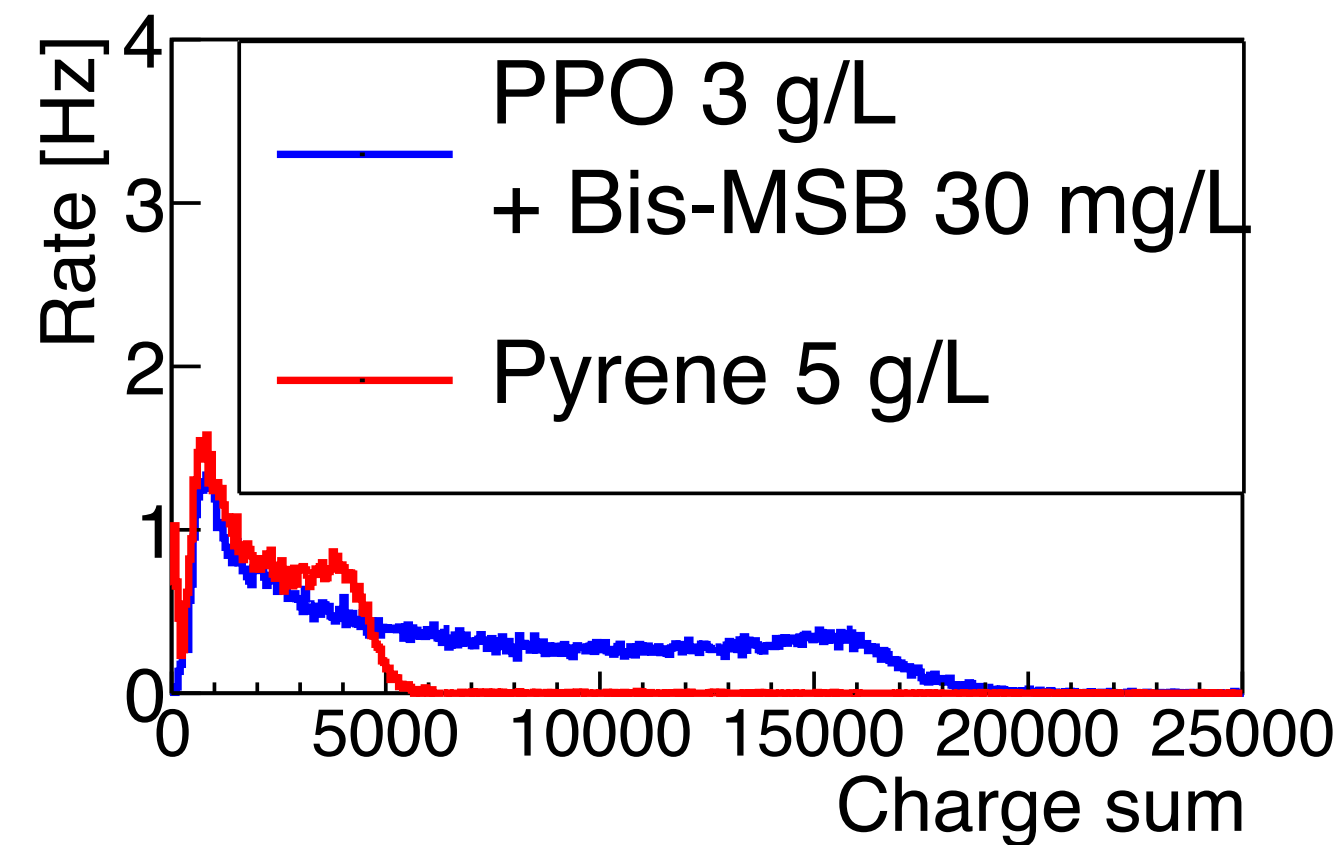


Shape	Cylindrical	Spherical
Radius (m)	7	7.25
Height (m)	14.5	-
Volume (m ³)	2232	1596
Mass (kg)	1920	1373
Number of PMTs	3700	3000

Size of buffer volume is under optimization.

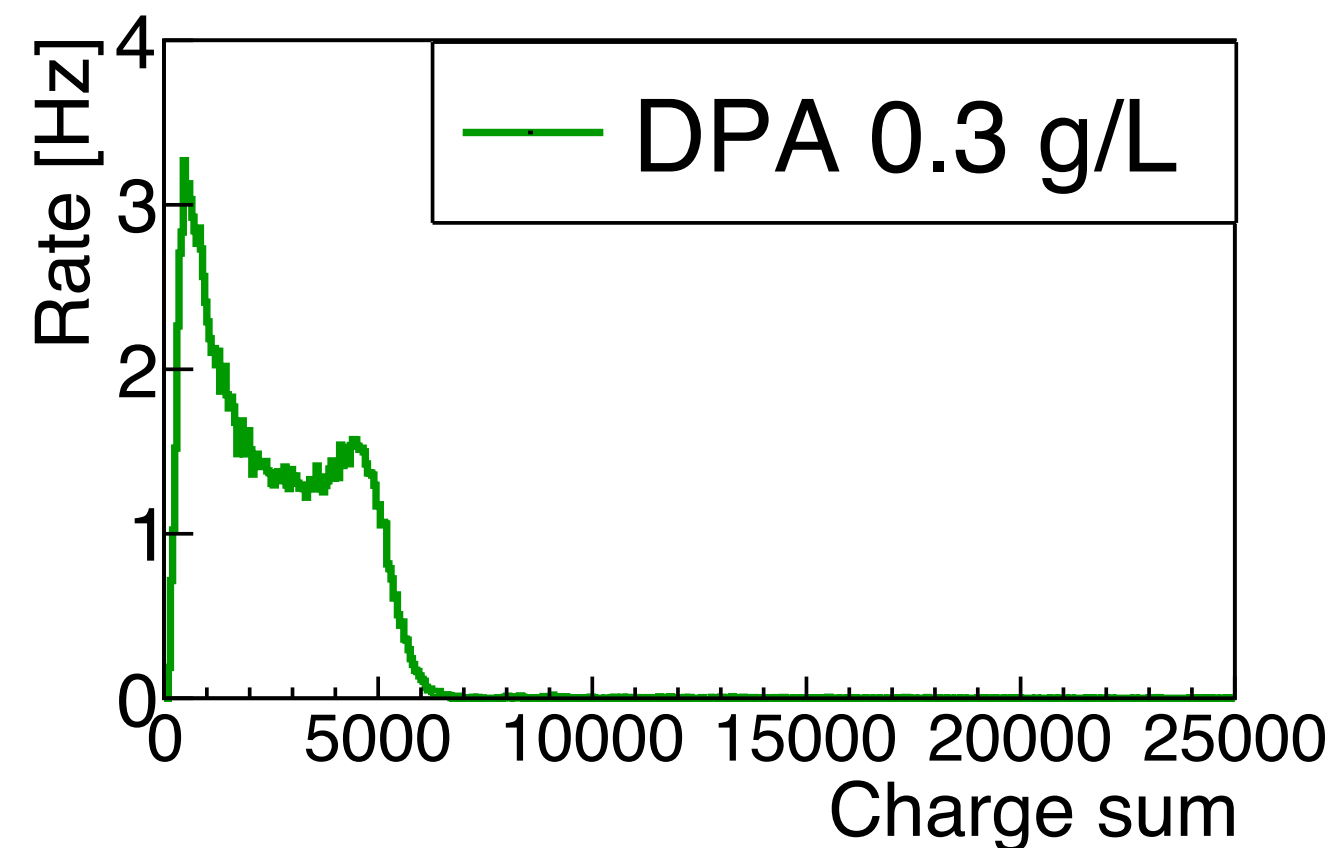
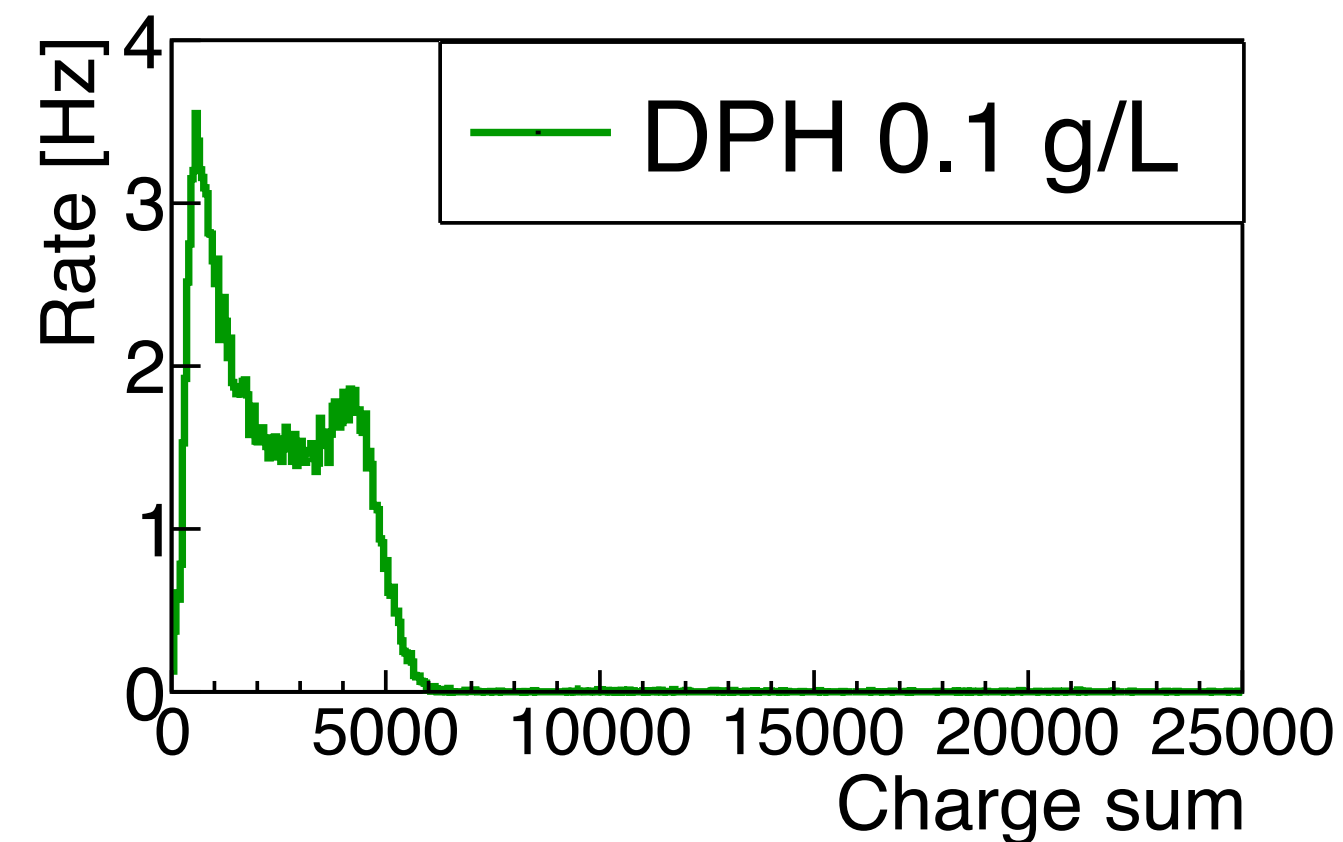
Target liquid scintillator

Our primary choice is “**slow scintillator**”, to separate Cherenkov from scintillation.
A chemical lab was constructed to initiate this R&D @ Yemilab.



Light yield (LY) measurements.

- PPO + Bis-MSB shows the largest LY.
- Others show similar LY.



Detailed R&D status can be found from

: <https://sites.google.com/korea.ac.kr/the-nueye-telescope/pubpresentations>

Photodetector

Our primary choice for the photodetector is **photomultiplier** technology.
Another possible option: LAPPD - complication of readout, cost issues have to be resolved.
(<https://sites.google.com/korea.ac.kr/the-nueye-telescope/pubpresentations>)

In the market, we have three major choices.

- To reduce the cost, our primary choice becomes N6082 (8 inch) + "light concentrator".

Model	R12860	N6203	N6082
Size (inch)	20	20	8
Peak wavelength (nm)	420	380	380
HV (V)	2000	1900	1750
Q.E. (%)	30	30	30
TTS (ns)	2.4	5	1.6
Supplier	Hamamatsu	NVT	NVT

Environmental backgrounds @ Yemilab

At the Yemilab site, HPGe is utilized, to measure the radioactive background from rocks.

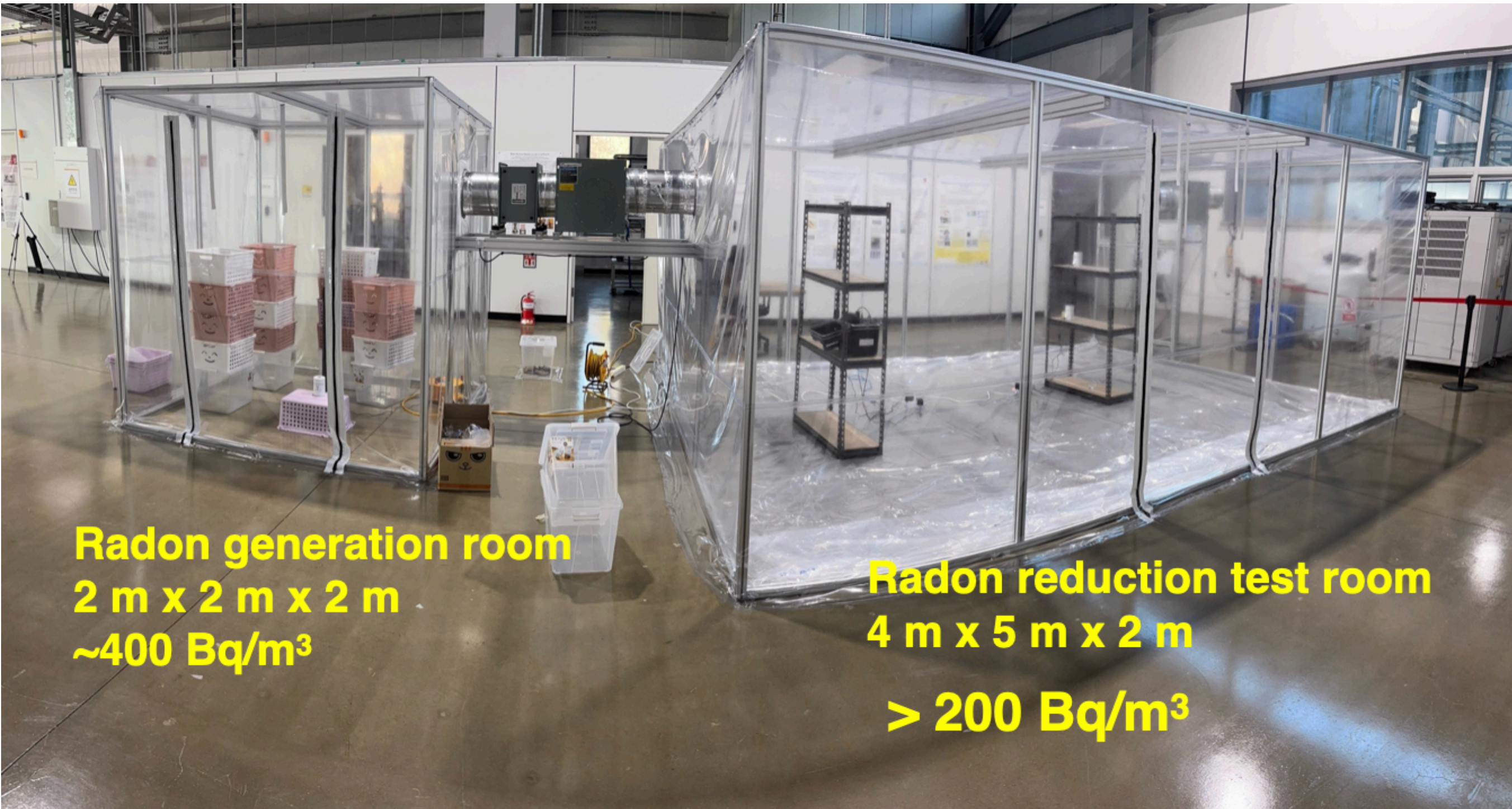
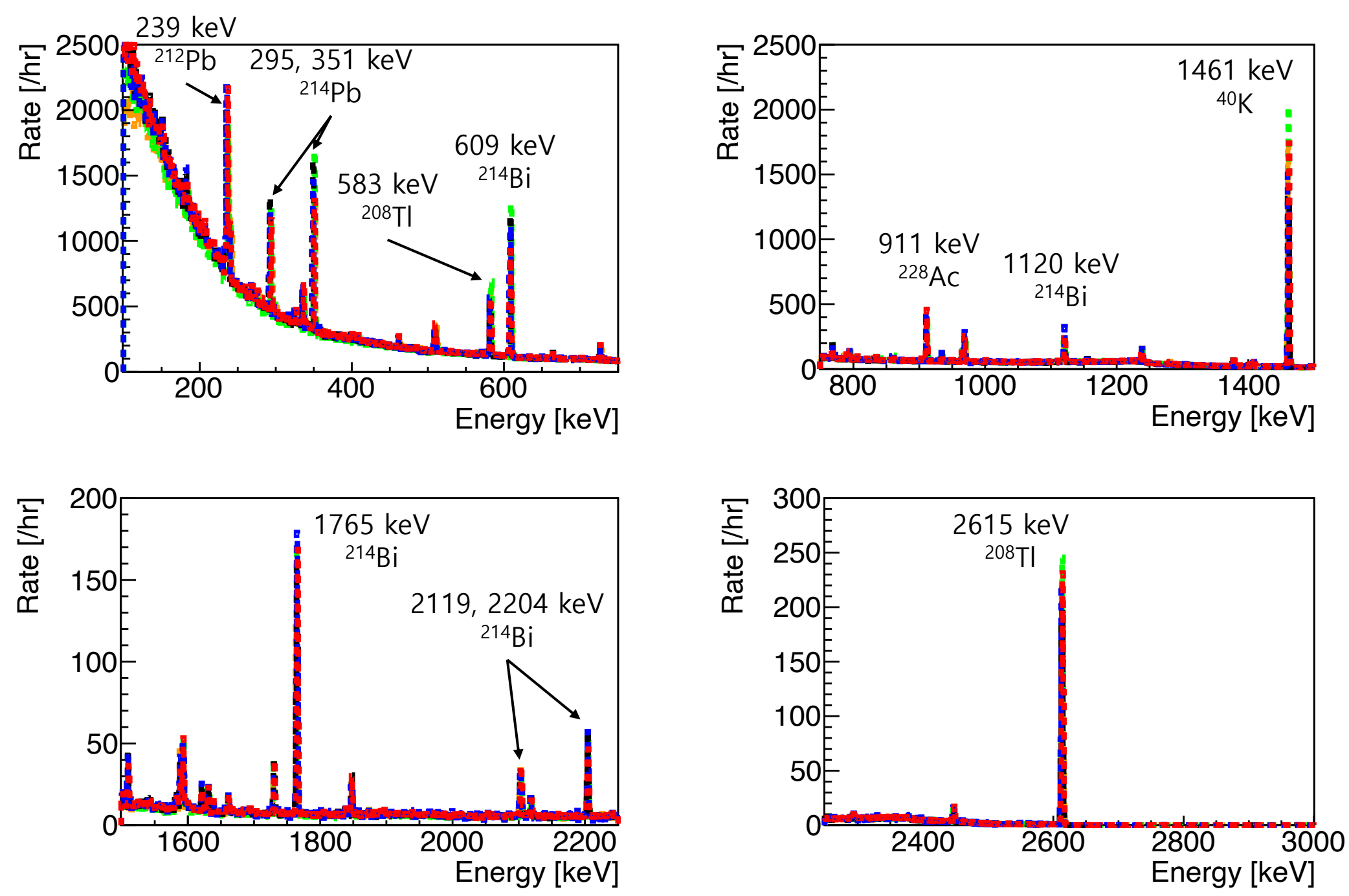
	Bq/kg		
	^{238}U	^{40}K	^{232}Th
Shotcrete	16.7 ± 0.6	447 ± 16	25.3 ± 0.6
Rock # 1	19 ± 2	618 ± 69	22 ± 2
Rock # 2	18 ± 2	872 ± 98	26 ± 2
Rock # 3	13 ± 1	561 ± 63	15 ± 1

Measured Radon activity

Location	Radon level (Bq/m ³)
Up	68 ± 14
Middle	84 ± 19
Middle (opposite)	118 ± 12
Middle (low)	125 ± 21
Hall center	148 ± 17

Dedicated Radon reduction system is required.

We are exploring a new method: silver-ion exchanged zeolite (PTEP 2024 023C01) @ Korea U Sejong campus.



Radon generation room
2 m x 2 m x 2 m
~400 Bq/m³

Radon reduction test room
4 m x 5 m x 2 m
> 200 Bq/m³

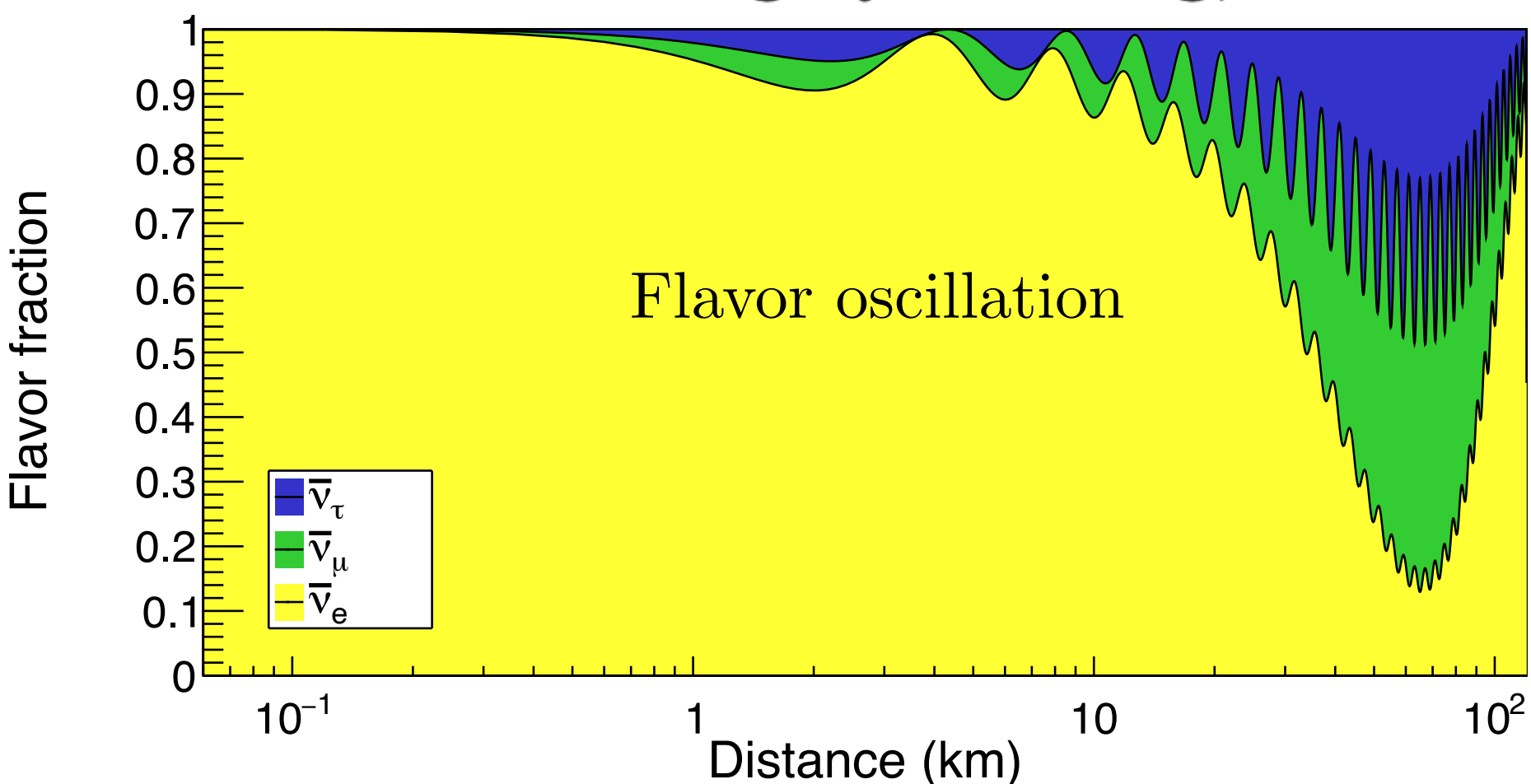
Software developments

ν Oscillation: a software package for computation and simulation of neutrino propagation and interaction

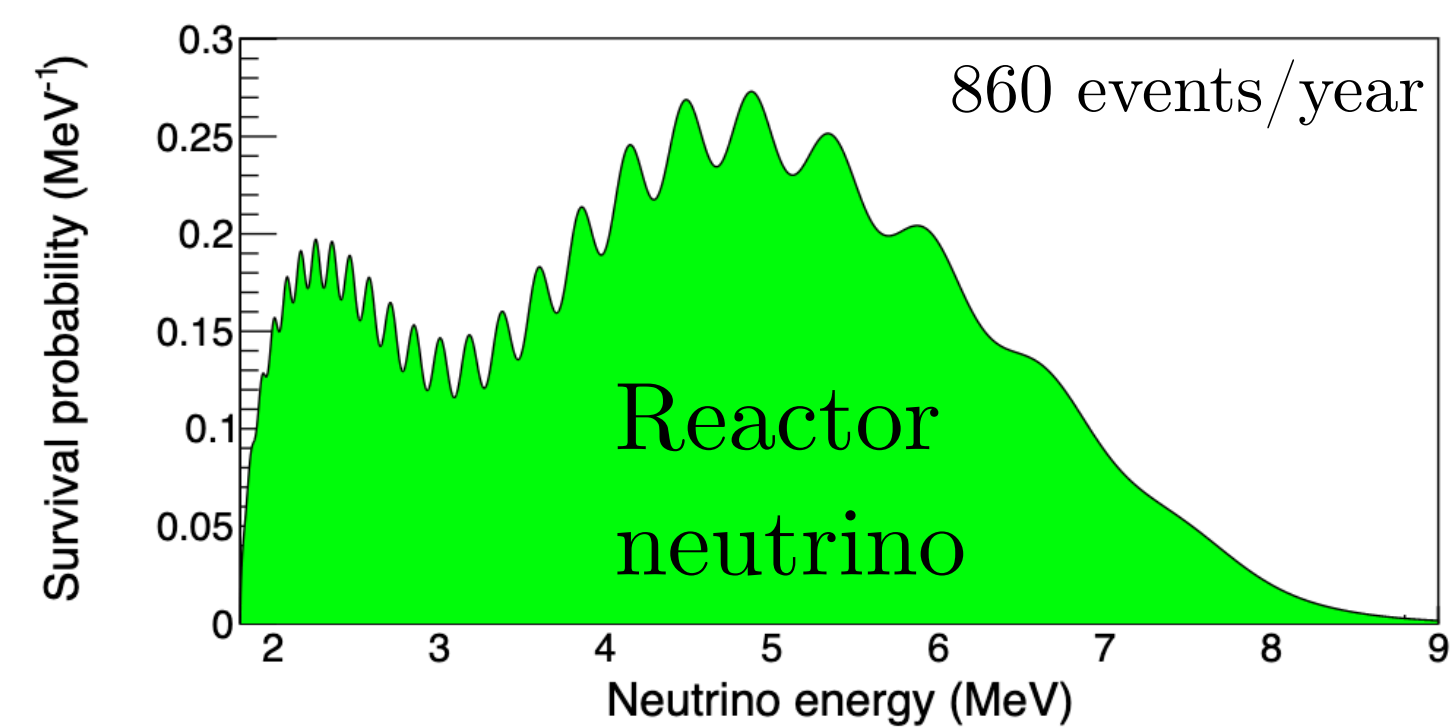
● Early study: K. Lee et al, J. Korean Phys. Soc. **85**, 381–388 (2024), <https://arxiv.org/abs/2401.13215>

Seong-hyeok Jang,¹ Eun-Ju Jeon,² Youngju Ko,² Kyungmin Lee,¹ and Eunil Won¹

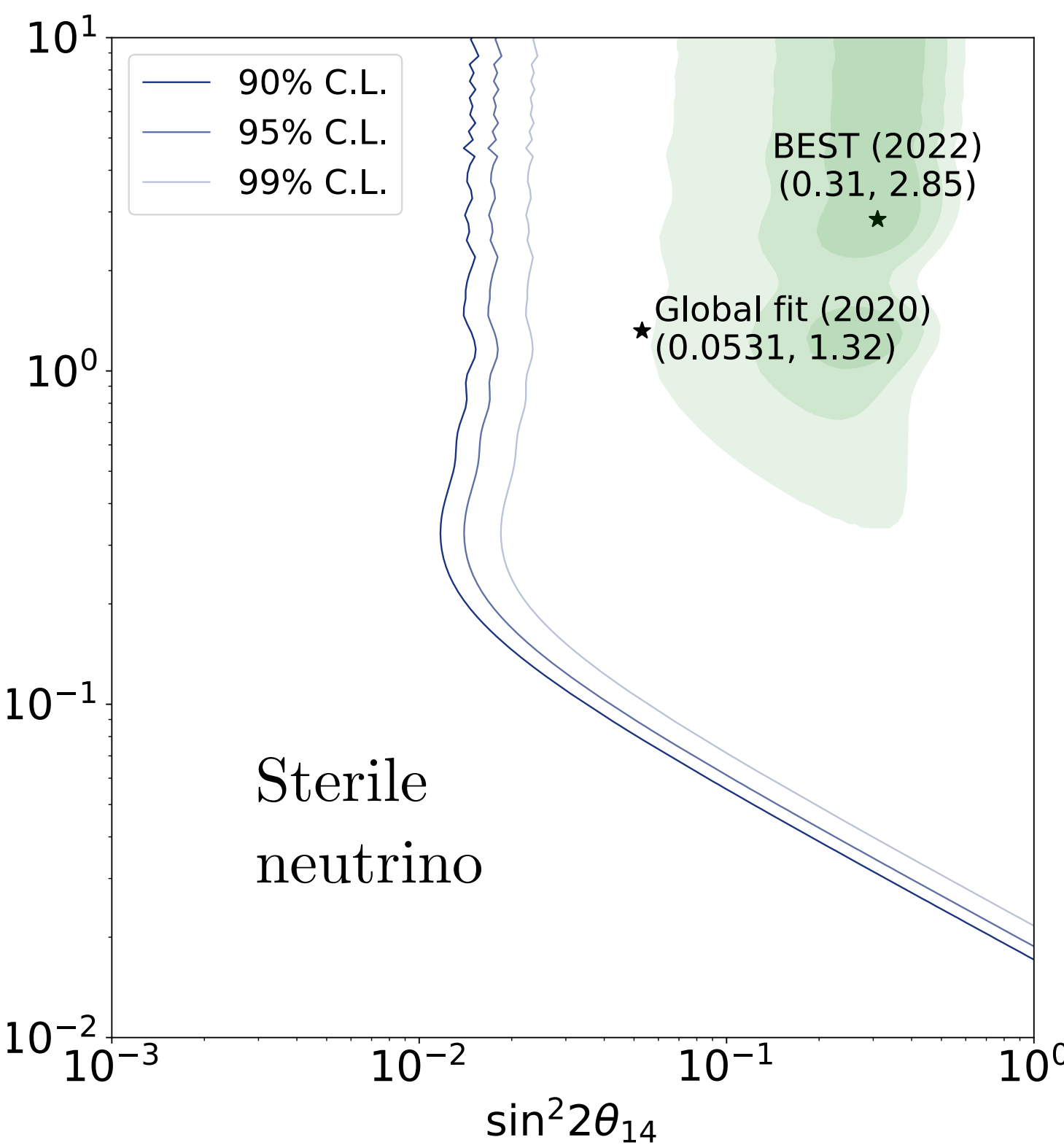
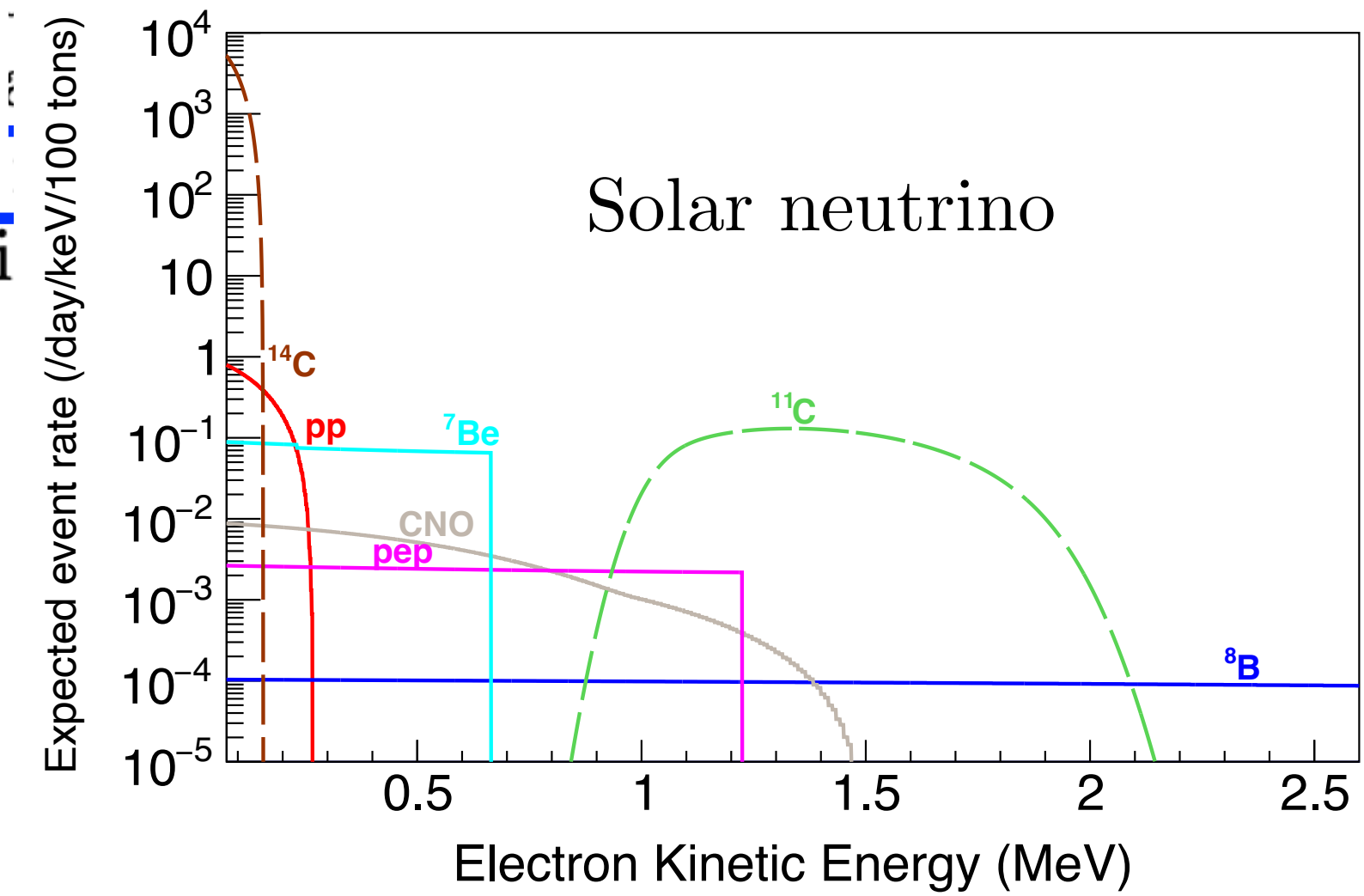
Physics, Korea University, Seoul 02841, Korea
Physics, Institute for Basic Science, Daejeon 34047, Korea



from the sun, and the oscillation of the neutrino oscillation with assuming a reactor located at 53 km away from the detector.



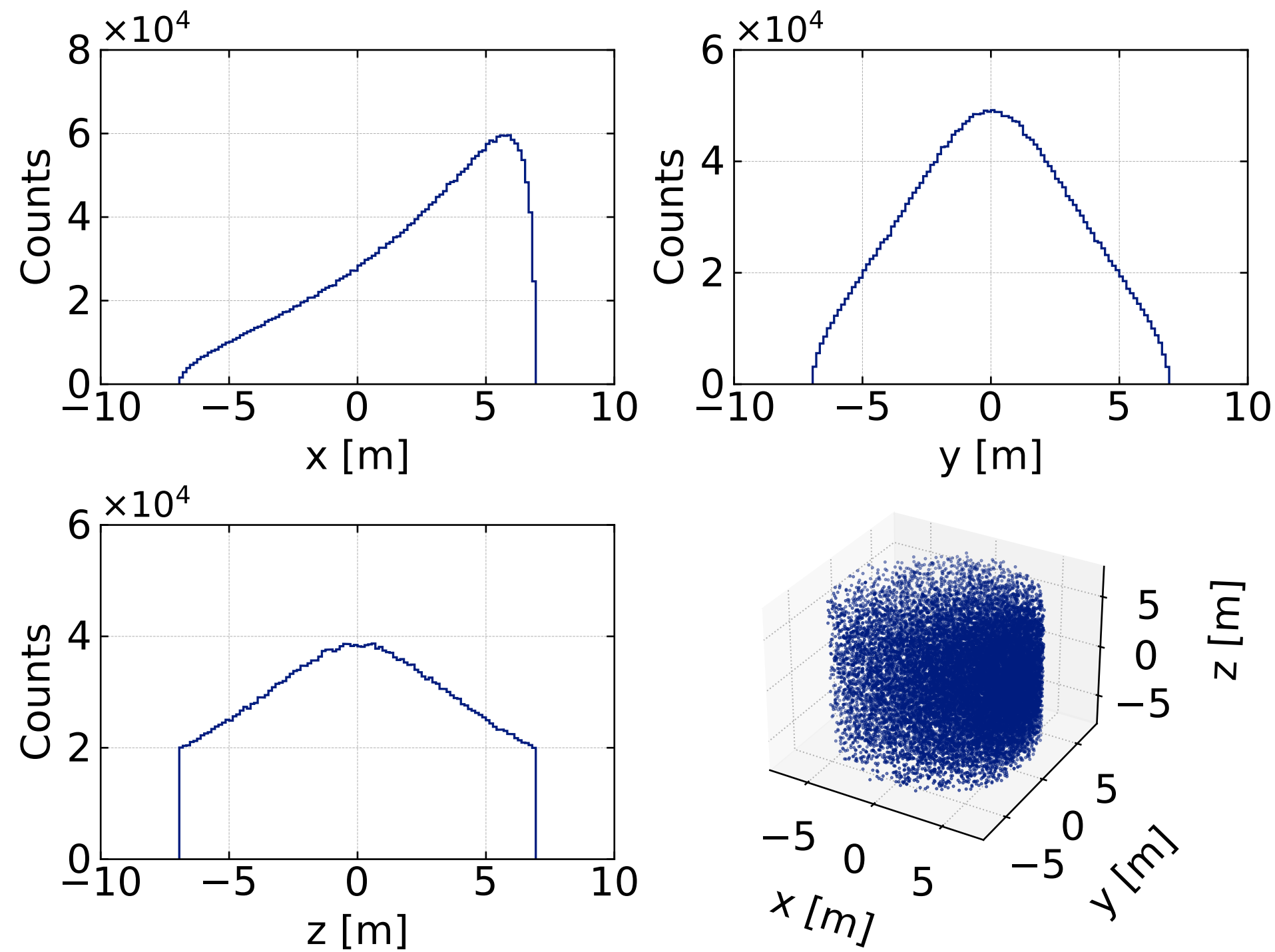
only phenomenon that cannot be explained by sterile neutrino interactions observed and ongoing or planned neutrino experiments on precise computations of neutrino oscillation. In this work, we develop a software package



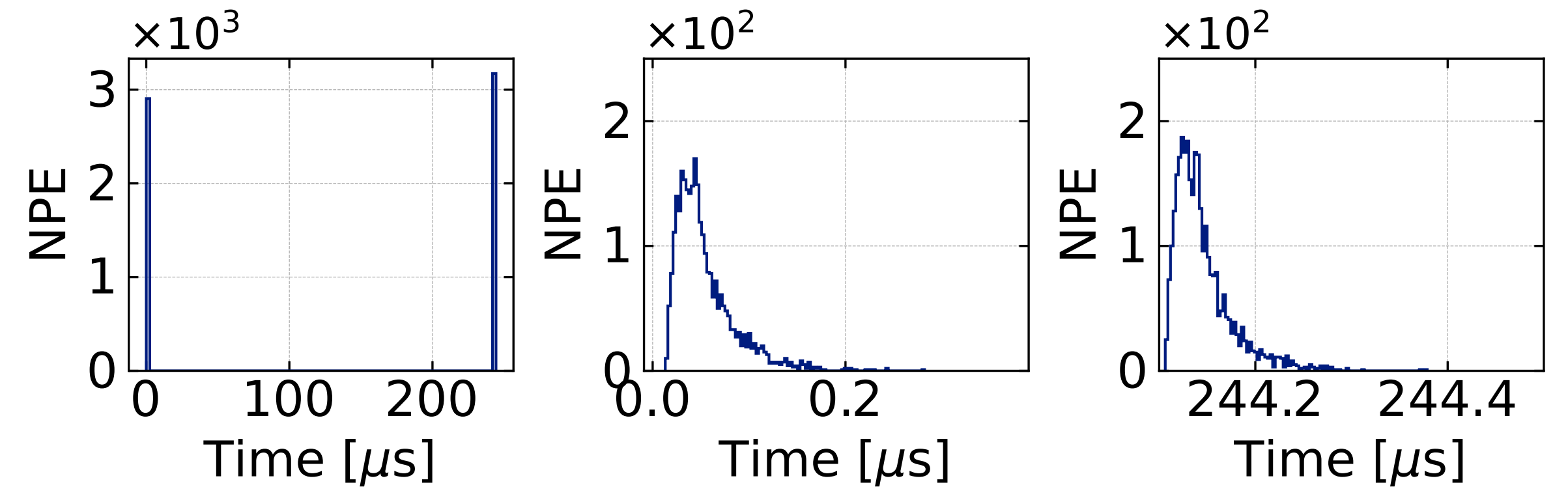
Software developments with Geant4

^{144}Ce $\bar{\nu}_e$ production simulation (Geant4) and reconstruction of inverse beta decays (IBD)

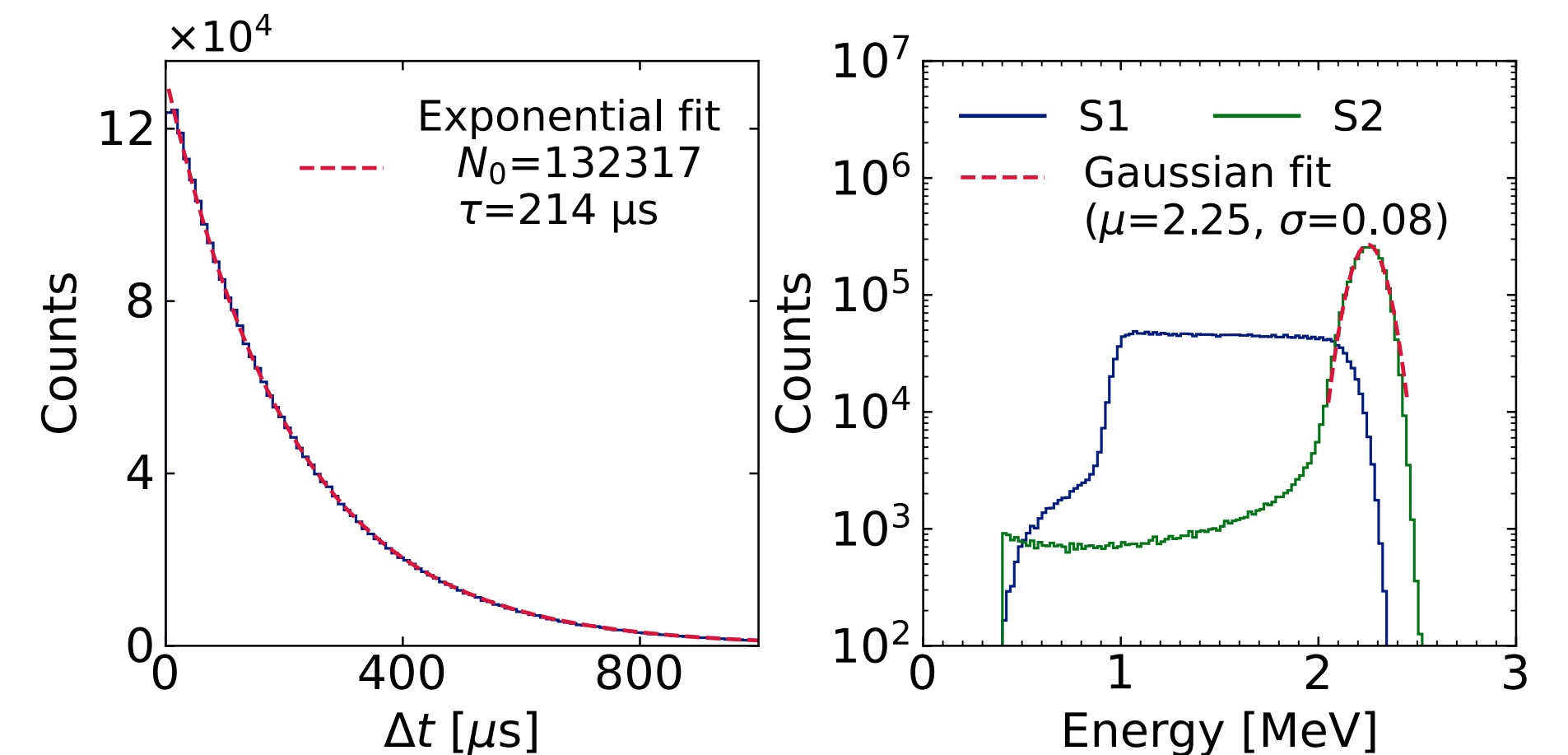
^{144}Ce at (9,5,0,0) m



Hit time distributions (S1, S2 together, S1 and S2 respectively)



Time difference btw S1 and S2 (left) and energy deposit (right)



IBD events trigger

- Require hits in 200 ns
- If $\text{NPE} > 400$, all hits in 500 ns constitute first cluster (S1)
- Search for the second cluster (same condition, S2)

A prototype ν EYE (1 tonne) construction

Volume : 1.2 m x 1.2 m acrylic tank: $O(1)$ tonne of LS.

Buffer : pure water or mineral oil.

PMTs : $O(30-60)$ PMTs of 10" R7081.

DAQ and HV

FADC: 500 MHz (to be purchased from Notice).

CAEN A7435SP (some parts have to be purchased).

Purpose

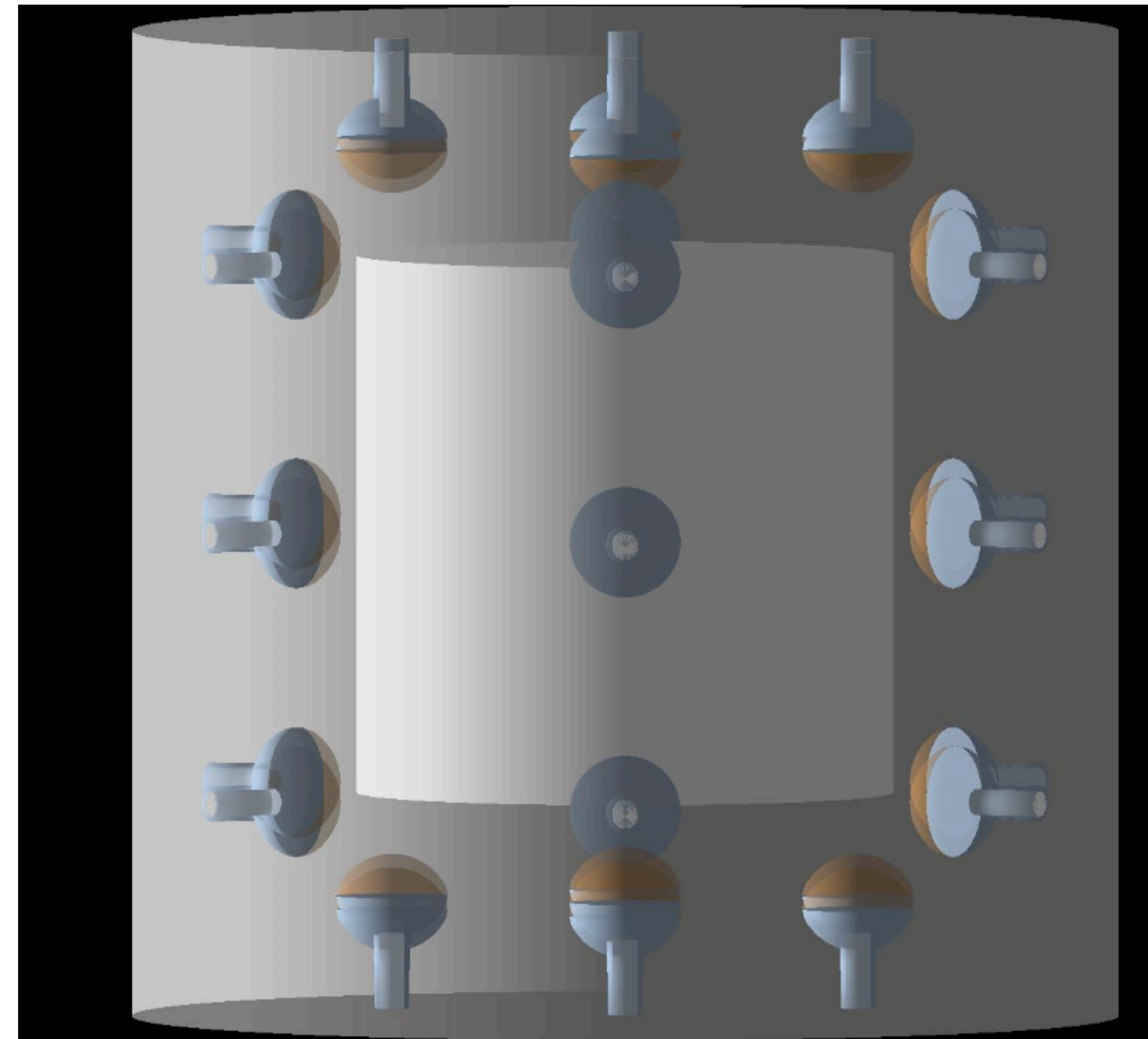
Study and optimize LS.

Measure the intrinsic background : 10^{-13} or 10^{-14} g/g.

To provide feedback to full scale ν EYE detector.

Optimize and validate the Geant4 simulation.

Construction started from summer of 2025.



A prototype ν EYE (1 tonne) construction @ Yemilab

To be air controlled (!) polyvinyl chloride structure was constructed: 12 m (l) x 6 m (w) x $[4 + 1.5]$ m (h)
Container, electronics, and DAQ are all to be installed in this experimental hut.
Plan: HV on early 2026.



Radio-purification (for one tonne)

Filtration

Removes optical impurities.
Removal of U/Th and K.



Water extraction

Removes dissolved radioactive metal ions
K, U, Th, Pb removal
Inorganic impurities

Water extraction
Custom build.

Vacuum Distillation

Removes high boiling point impurities
Metal & Oxide, U/Th, K, Bi, Po/Pb



Nitrogen gas stripping

Remove dissolved gases

Now @ Yemilab

Glove box (see the picture on the right)
Other components are being purchased.



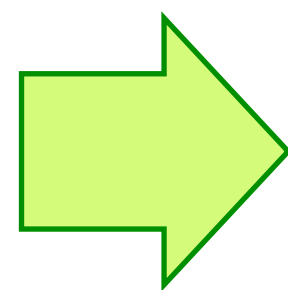
Alternative Detector Technologies

Water based (WbLS) Technique

CPNR, Chung-Ang U. BNL and so on.

Opaque LS Technique (see talk by A. Cabrera on Sunday)

- New concept: opaque liquid scintillator
- Created photons are confined locally (Rayleigh, Mie scatterings)
- Such photons are read out by optical fibers + SiPM



We look at potential for ν EYE: R&D stated.

- (500 mL LAB + PPO 1.5 g) + parafin wax (10 g).
- Heating for 20 min. to melt the wax., and cool down.



CDR Preparation

CDR preparation

- To promote the ν EYE project to the funding agency.
- To communicate with the neutrino community more efficiently.
- To identify issues, missing items, and solve problems by ourselves.
- Timeline: “finalize” by the end of 2025.

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CDR authorship as of today.

The ν EYE Neutrino Telescope Conceptual Design Report

Thank you all for
your support!

Shaomin CHEN ¹, Davide Franco ², K. K. Joo ³, Chang Hyon Ha ⁴, Jong-Chul Park ⁵, M.Pac, ⁶, Pouya Bakhti⁷, Meshkat Rajae⁷, Seodong Shin ^{7,8}, Young Ju Ko ⁹, Bo-Young Han ¹⁰, Jihoon Choi ¹¹, B. R. Ko ¹², HyangKyu Park ¹², Gihan Hong ¹³, Jaebak Kim ¹³, Minseo Kim¹³, Kyungmin Lee ¹³, E. Won ¹³, Jae Hyeok Yoo ¹³, J.Y. Cho ¹⁴, J.Y. Lee ¹⁴, D.W. Jeong ¹⁴, H.J. Kim ¹⁴, Sin Kyu Kang ¹⁵, Myung-Ki Cheoun ¹⁶, V. Kornoukhov ¹⁷, V.V. Kobychov ¹⁸, V.I. Tretyak ^{18,19}, and

Steve Elliott ²⁰

All of you are kindly invited to sign up and contribute!

ν EYE web: <https://sites.google.com/korea.ac.kr/the-nueye-telescope>
<http://nueye.korea.ac.kr>

The NuEYE Experiment at Yemilab

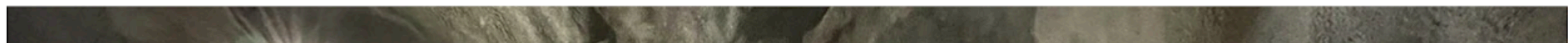
In September 2022, a new underground laboratory, [Yemilab](#), was completed in Jeongseon, Gangwon Province in South Korea, with a depth of 1,000 m. In the laboratory, the largest site is the LSC Hall, combining a square dome measuring 22 m (width) by 22 m (length) by 8 m (height) on top, with a cylindrical pit having a diameter and depth of 20 m. The pit has a volume of 6,200 m³ and serves as a multipurpose space for detectors. For a liquid type, about a 2 kilo-tonne detector can be hosted as an example. The NuEYE experiment is a new proposed underground neutrino telescope at [Yemilab](#) for a multi-purpose neutrino science.

NEWS | 30 May 2024

Disputed dark-matter claim to be tested by new lab in South Korea

A multi-million dollar facility is hoping to put a 21-year-old debate about dark matter to rest.

By [Gemma Conroy](#)



Summary

The ν EYE neutrino telescope: a multi-purpose, 2 kilo tonne LS detector @ Yemialb.

Selected physics cases are discussed.

- Sterile neutrino search.
- Solar neutrino: “up-turn” in the survival probability, metallicity (not discussed).
- Reactor neutrino: Yemilab is at the first minimum of Hanul reactor.

Default designs of ν EYE detector are presented.

- LS: slow LS (other options under consideration).
- PMT: 8 inch version + light concentrator (for now at least).
- Software : IBD, generators, $e^- - \nu_e$ scattering (not discussed).
- Alternative options.

From this summer, **one tonne prototype ν EYE** was started.

We are looking for domestic and international collaborations.

Please join us for future !