

여미랩 중성미자 검출기 - 뉴아이

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

고에너지 물리 연합 워크숍

2025년 11월 19-22일

전남대학교

고려대학교 물리학과

원은일

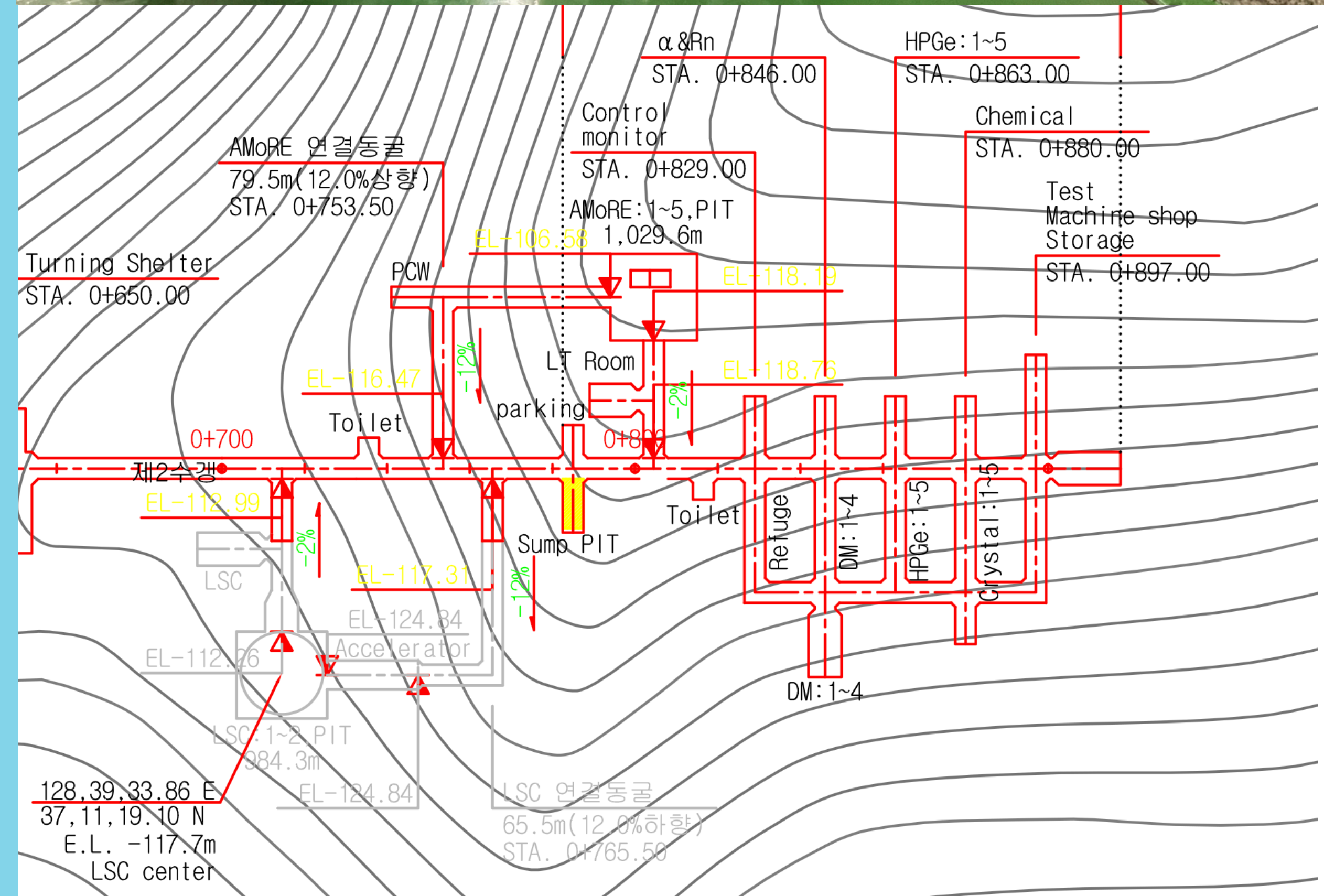
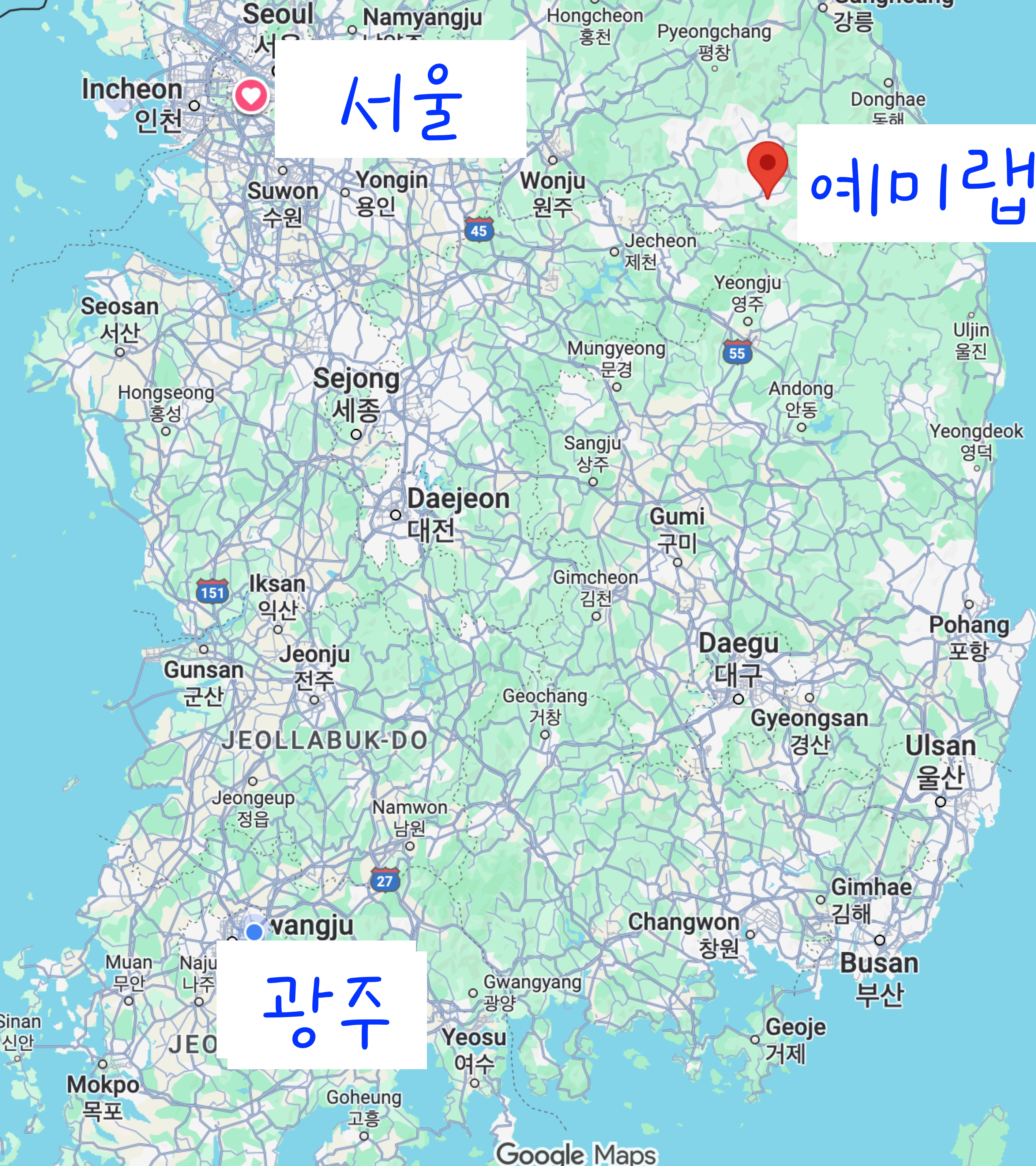
뉴아이 웹: <http://nueye.korea.ac.kr>

순서

예미랩 소개

- 예미랩 지하 대용량 공간
 - 현재 생각하고 있는 다목적 실험 - 뉴아이
 - 비활성 중성미자
 - 태양 중성미자 물리학
 - 원자력 발전소 중성미자 물리학
- 검출기 연구 상황
 - 1 톤 검출기 prototype 건설 현황

여미랩



[nature](#) > [news](#) > article

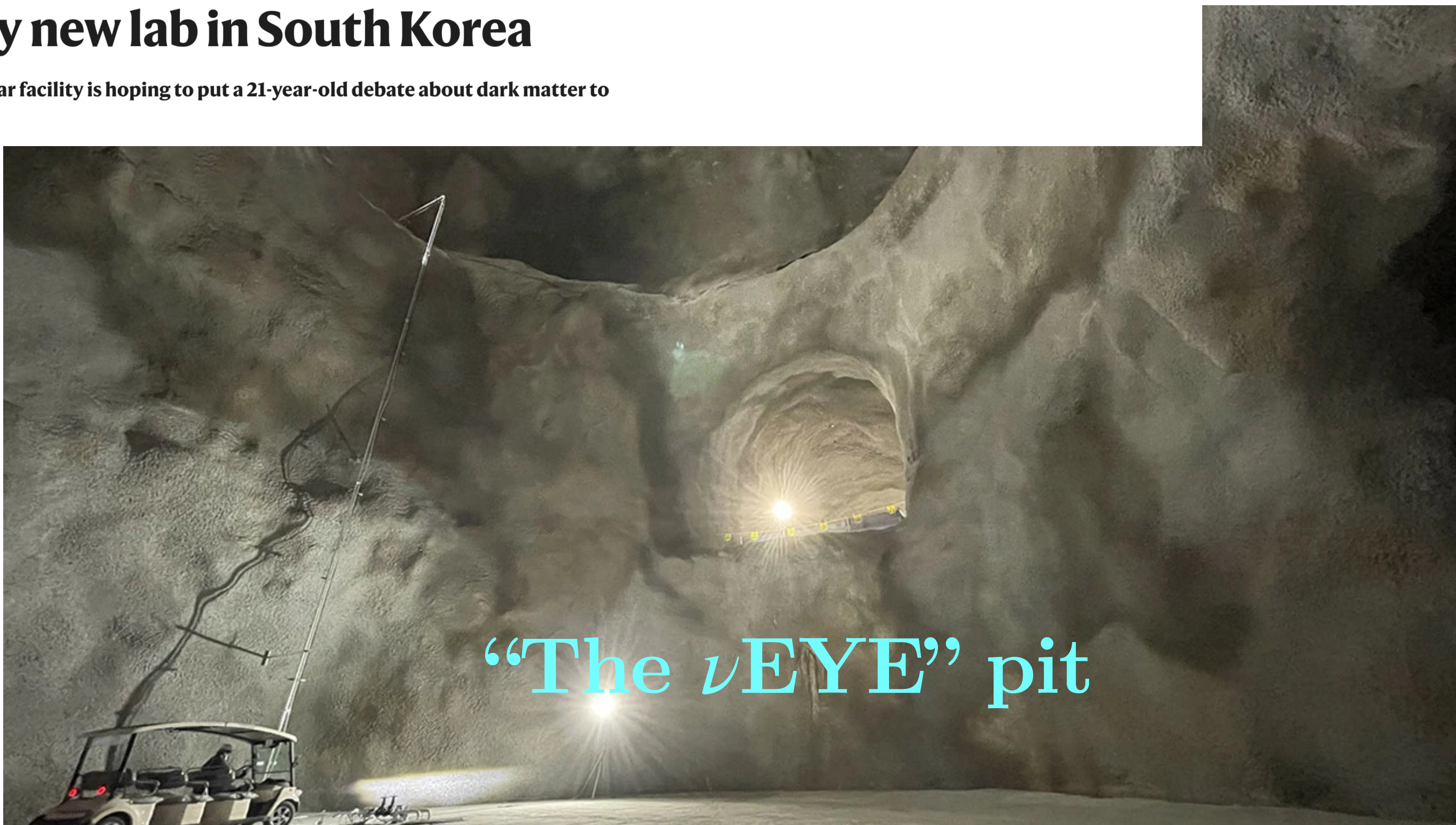
NEWS | 30 May 2024

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.

1000 미터 깊이
(<https://arxiv.org/abs/2402.13708>)

약 2 킬로톤 검출기 설치 가능 공간 + 가속기 공간



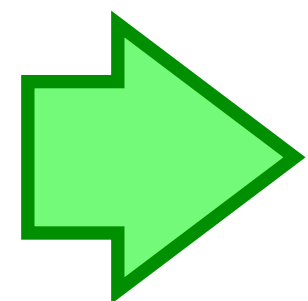
물리 연구 주제

지난 20년 동안 비활성 중성미자 탐색 상황

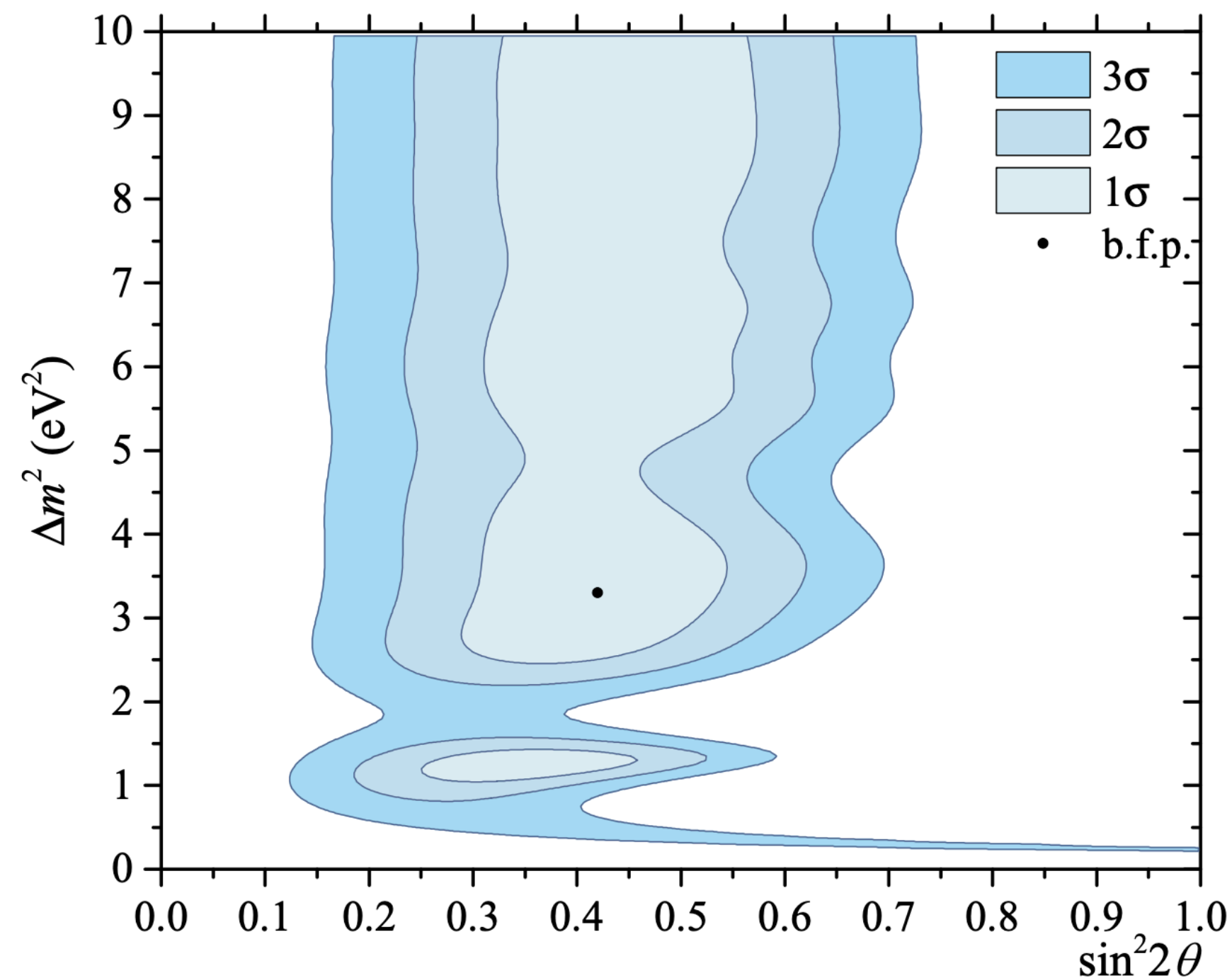
LSND 이상 신호 징후 이후, 중성미자 분야는 비활성 중성미자 논의가 중요한 부분 중 하나 이었음.

- KARMEN (neutron spallation) LSND 확인 못함.
- MiniBooNE ($\nu_e + \bar{\nu}_e$) LSND 와 유사, 그러나 저 에너지 excess.
- μ BooNE disfavors MiniBooNE and LSND (그러나 완전히 rule out 못함).
- 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 방사선동위원소, radiochemical 방법)



독립적 실험 검증 필요



Baksan Experiment on
Sterile Transitions (BEST)

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

비활성 중성미자? (예: two talks in Neutrino2024)

June 21, 2024 (v1)

Presentation

Open

Sterile ν : review of positive hints

Gorbunov, Dmitry

Plenary talk at the Neutrino 2024 conference. Session 14: Reactor neutrinos.

Part of [Neutrino 2024 \(Talks\)](#)

Uploaded on September 13, 2024

35

45

June 21, 2024 (v1)

Presentation

Open

Sterile ν : review of negative hints

Danilov, Mikhail

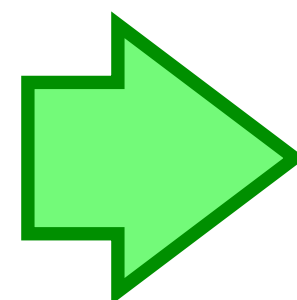
Plenary talk at the Neutrino 2024 conference. Session 14: Reactor neutrinos.

Part of [Neutrino 2024 \(Talks\)](#)

Uploaded on September 13, 2024

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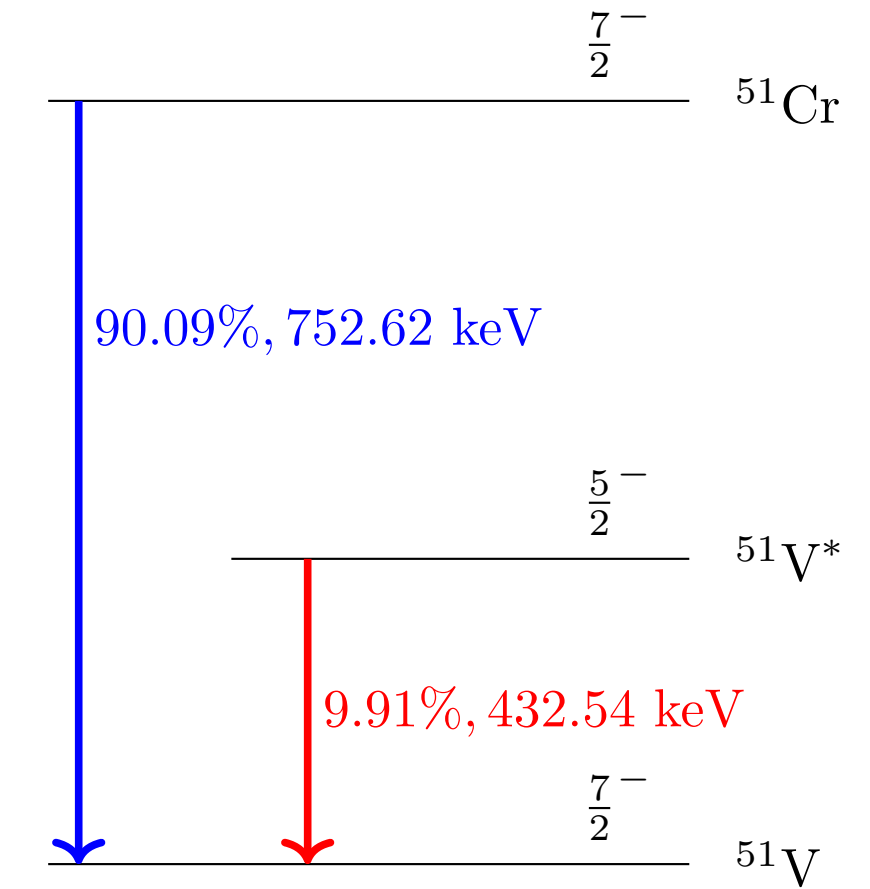
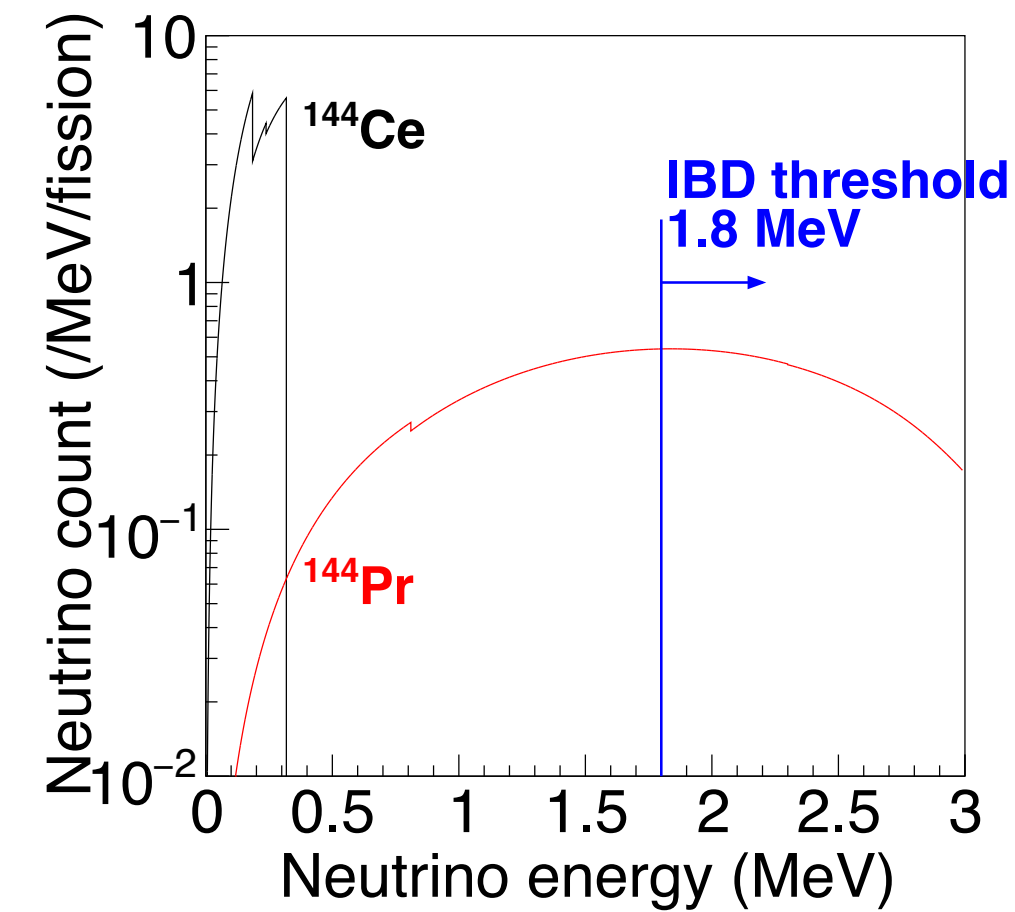
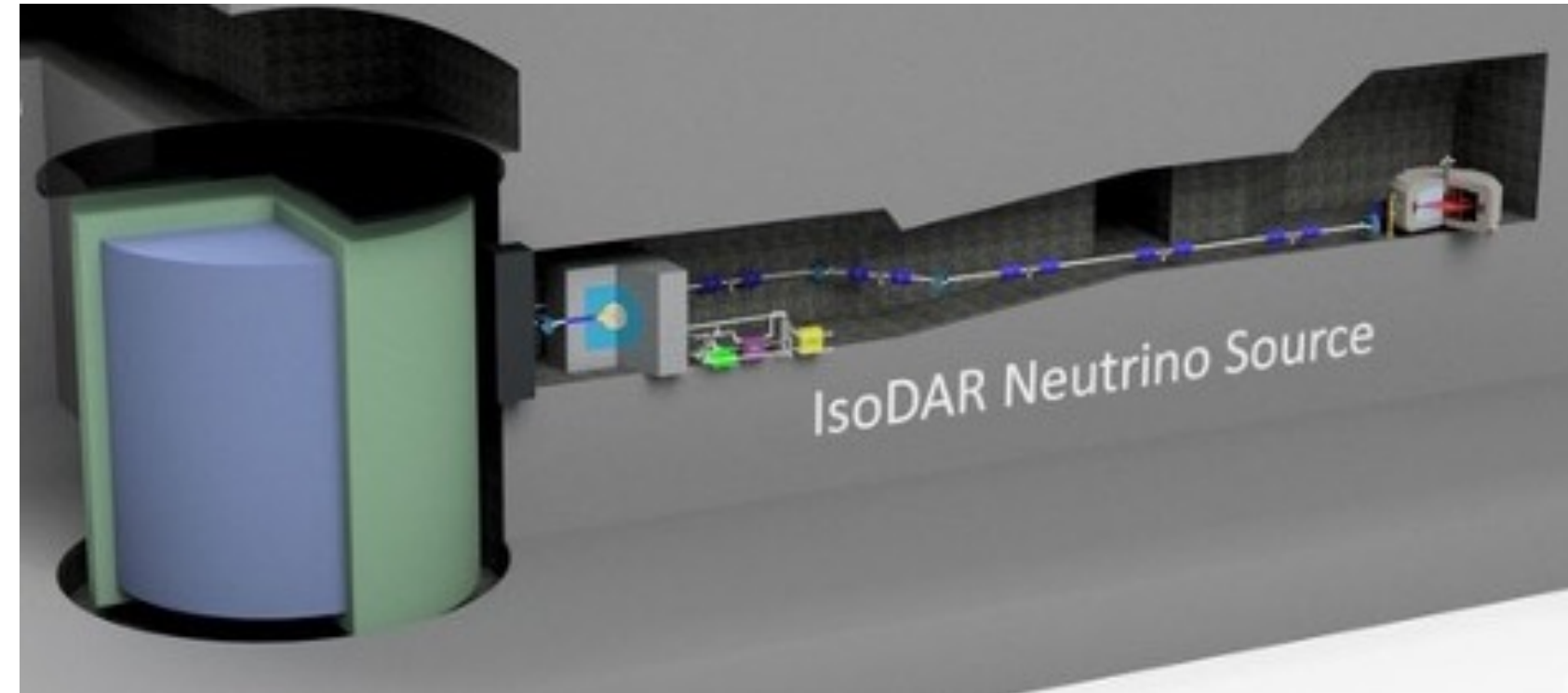


BEST 실험 결과 검증 필요.

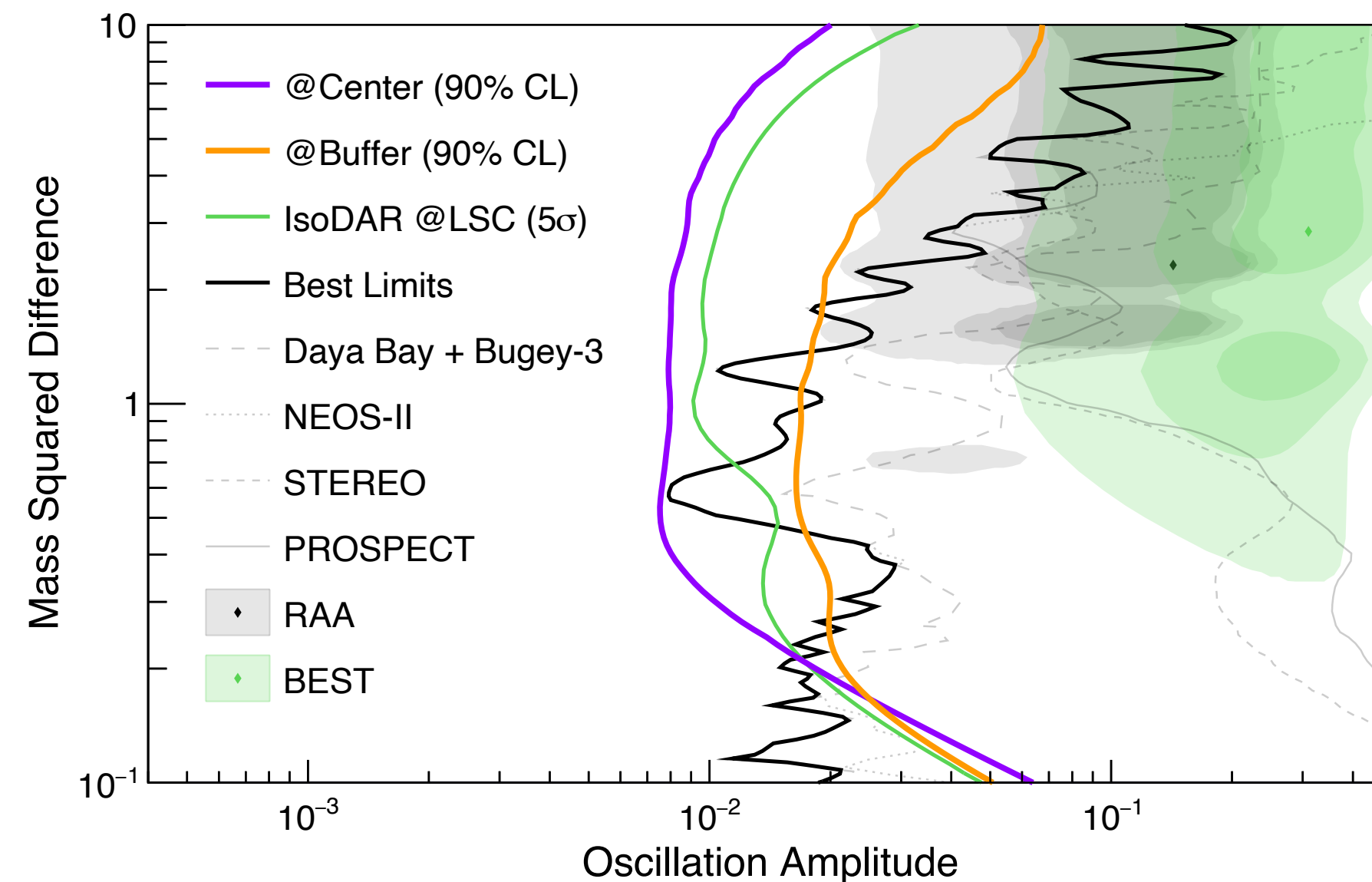
뉴아이 검출기와 비활성 중성미자

선택 1: 고전류 가속기 (IsoDAR) + 실시간 검출

선택 2: 방사선동위원소 + 실시간 검출



(Isotope Decay-At-Rest): 미국 주도

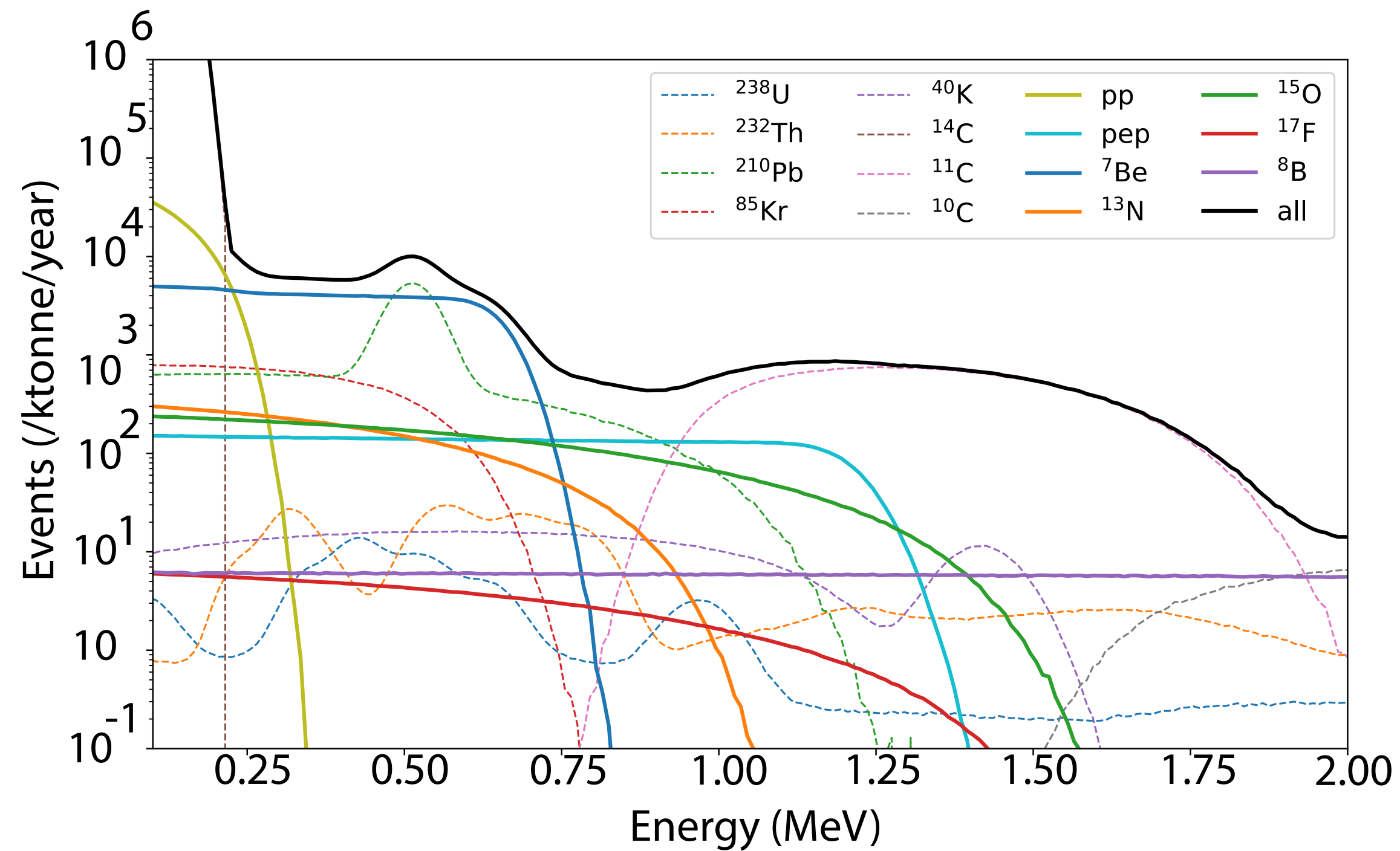


두가지 옵션 모두 **BEST** 결과 검증 가능.

태양 중성미자 물리학 with ν EYE

핵심 연구 주제: **observation of the “up-turn”**.

- Radio-purification 필요.

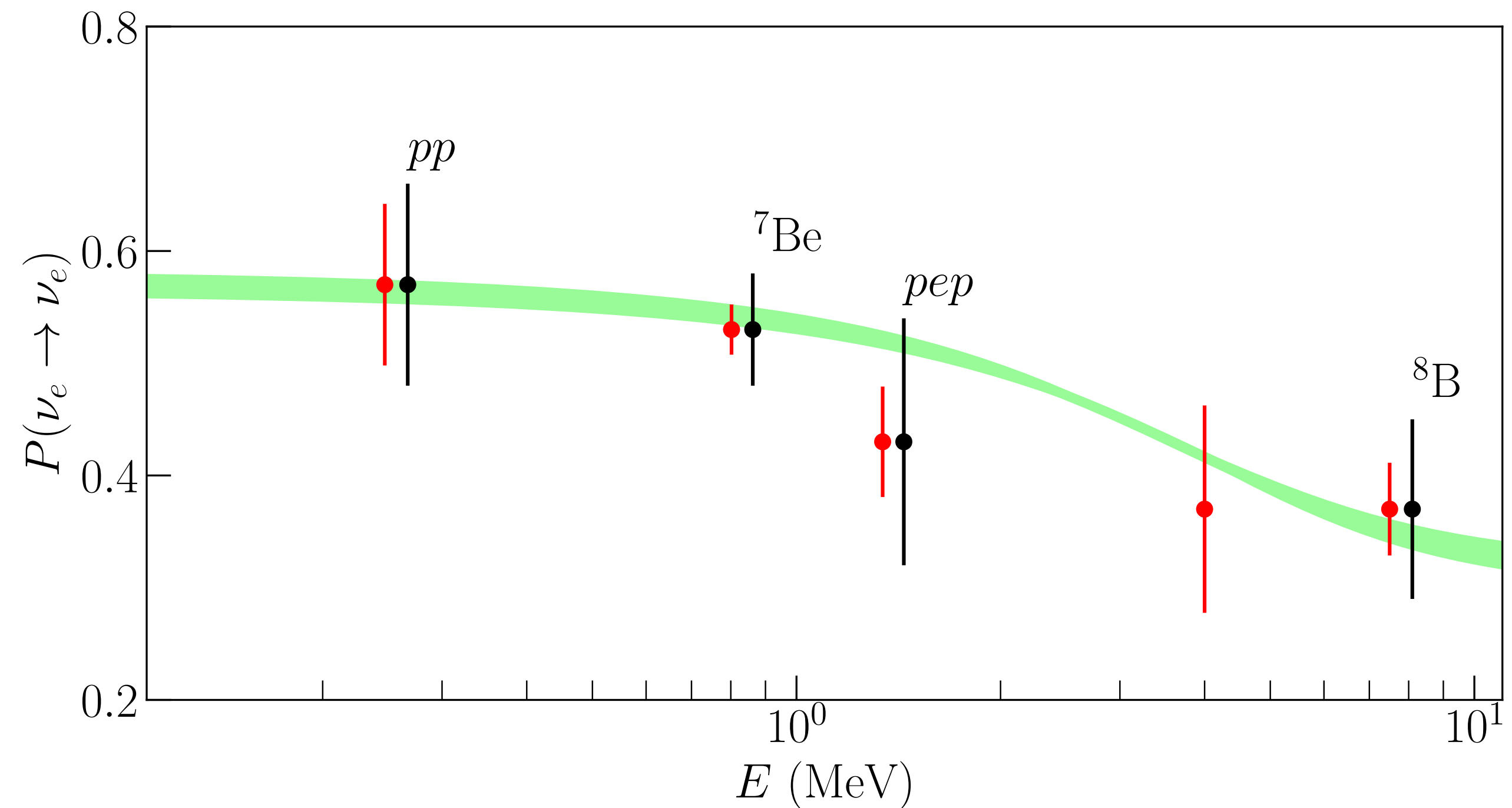


Detailed understanding of signal/background (reduction of background) is critical.

For pp , error doesn't scale with $1/\sqrt{N}$ due to pile up of ^{14}C .

Red: ν EYE (5 년)

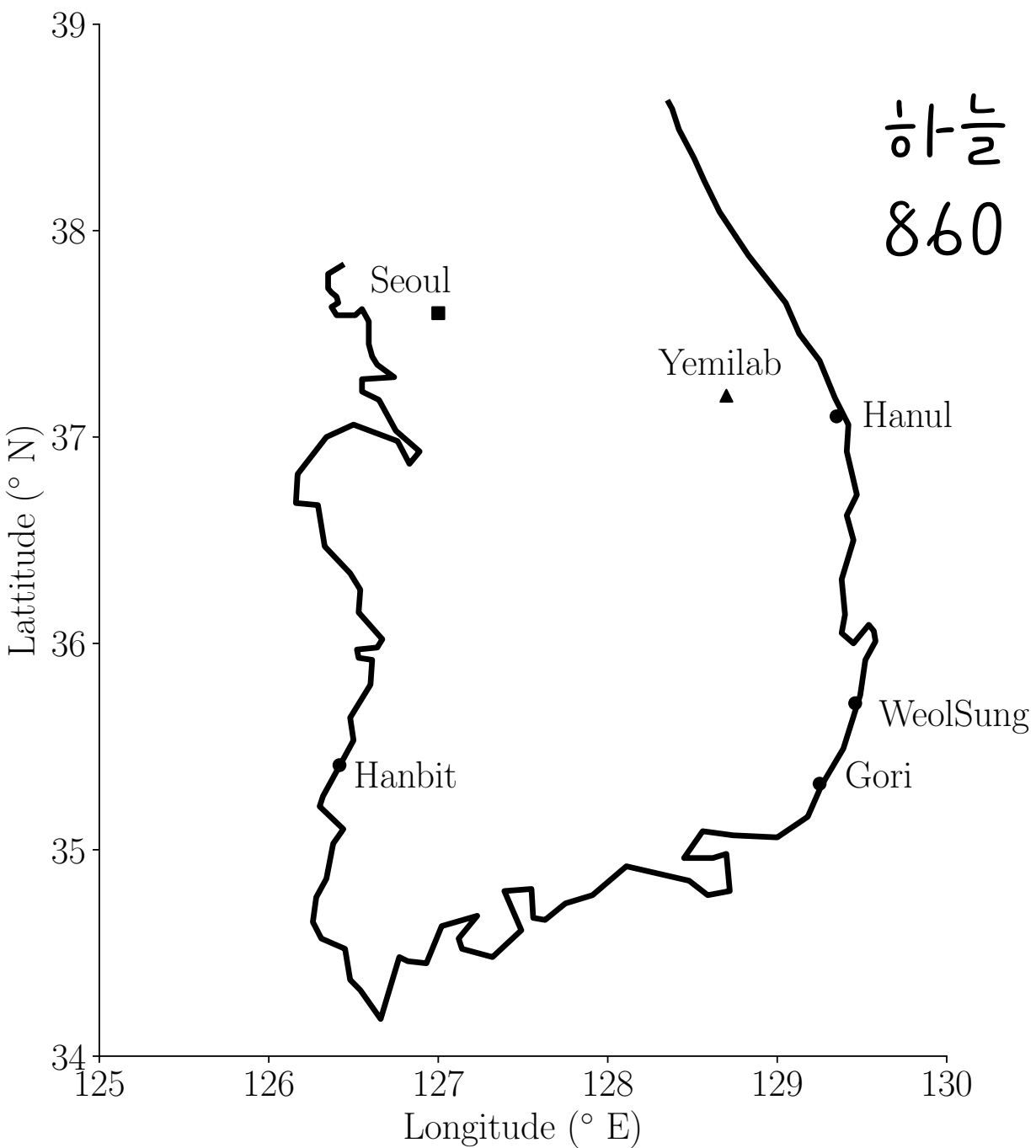
Black: Borexino



↔
 ν EYE 가 몇개의 점을 찍을 수 있음.

원자로 중성미자 with νEYE

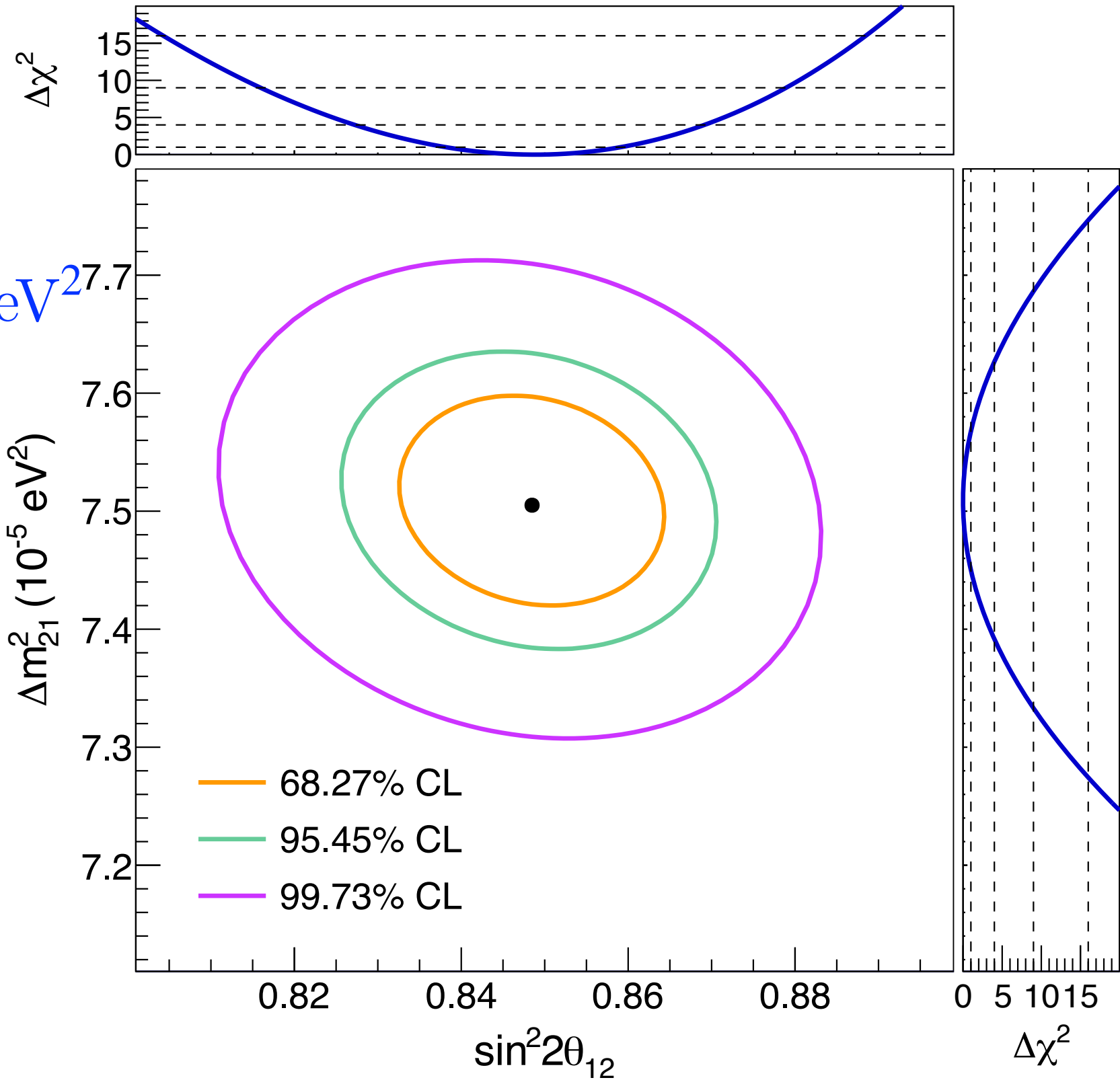
The JUNO experiment will measure 3-ν oscillation parameters with high precision.
But JUNO findings **need to be validated**: the νEYE is also at the first minimum.



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

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

νEYE 민감도 (5 year run)



$\sigma_{\Delta m_{21}^2} = (0.024) \times 10^{-5} \text{ eV}^2, \sigma_{\sin^2 2\theta_{12}} = 0.0016$
(JUNO 6 year projection, ICHEP2024)

중성미자 없는 이중 붕괴 탐색 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.

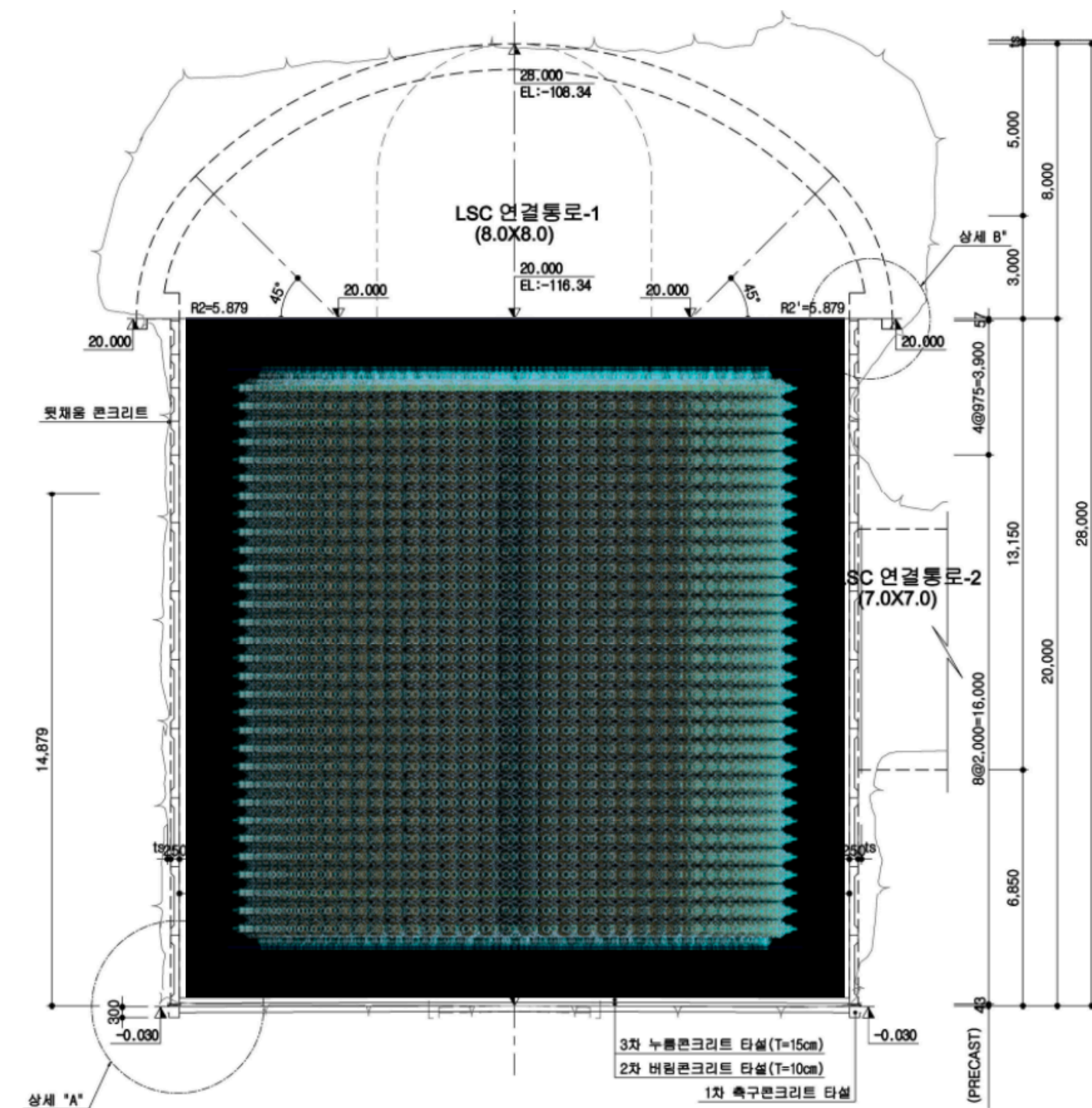
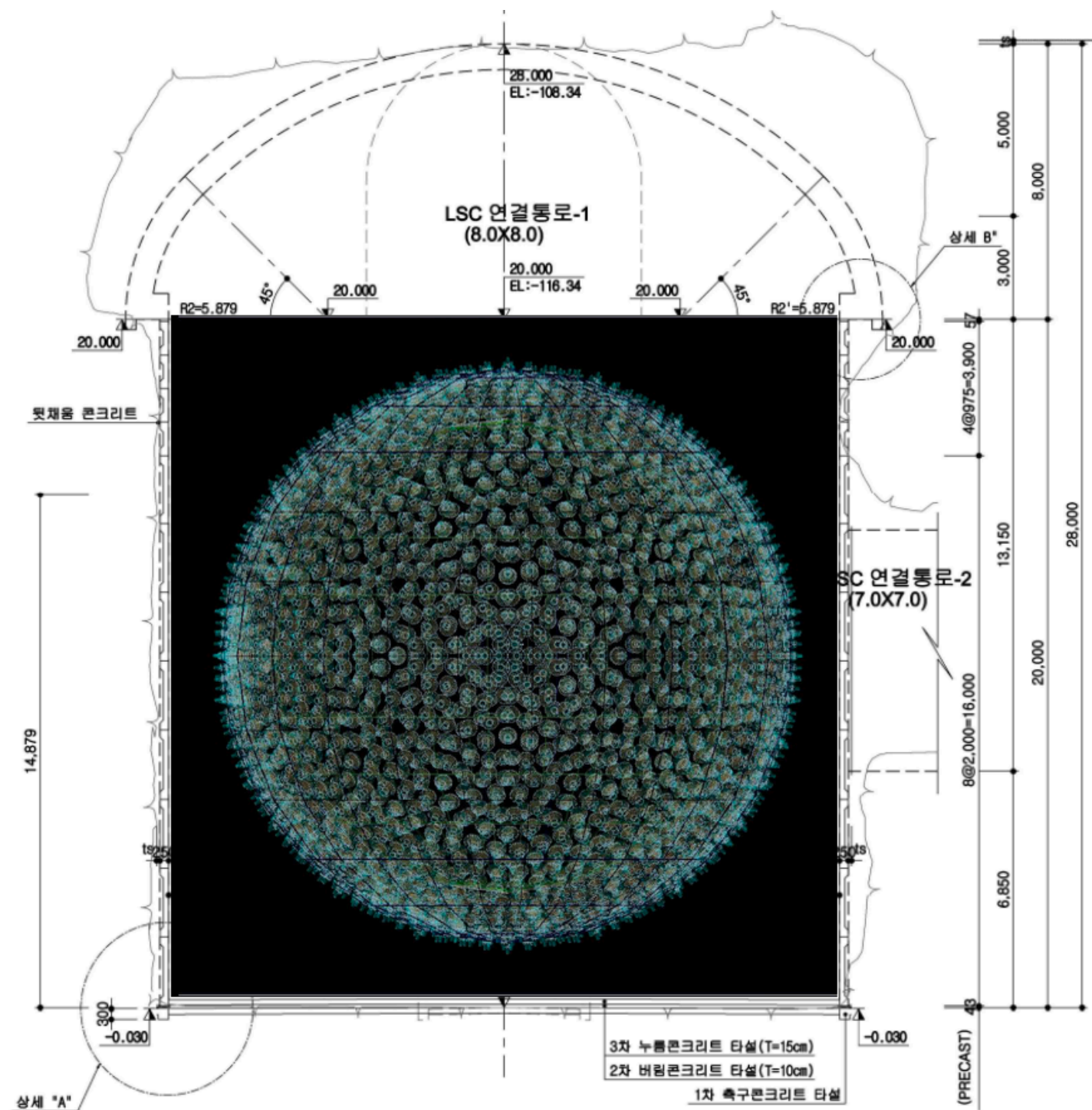
매우 오랜 시간의 연구 필요 (10 년)

검출기 설계

기본 검출기 개념

A 2 kilo tonne 액체 섬광기 (the actual target-mass is smaller).

At this moment, we consider two options: **spherical** or **cylindrical**.

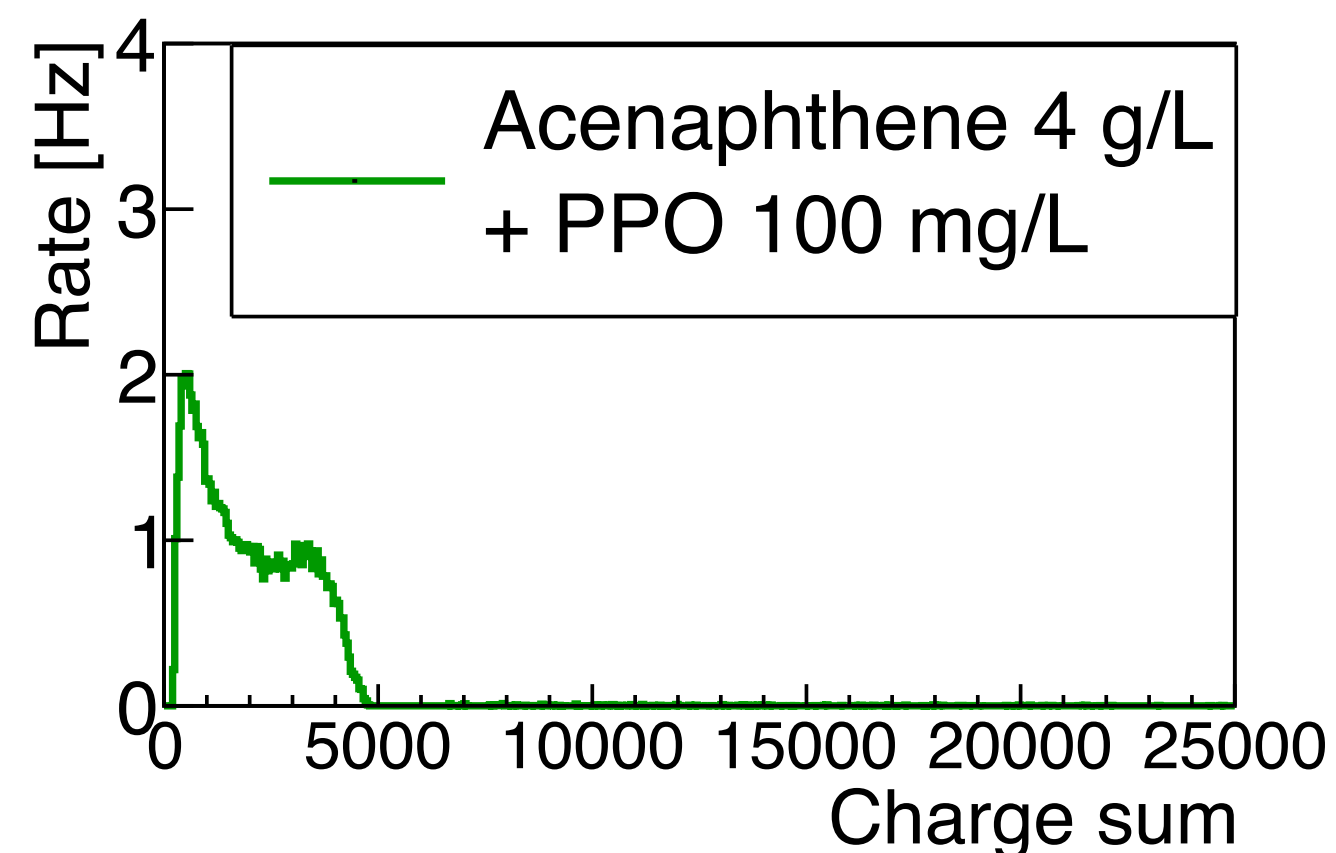
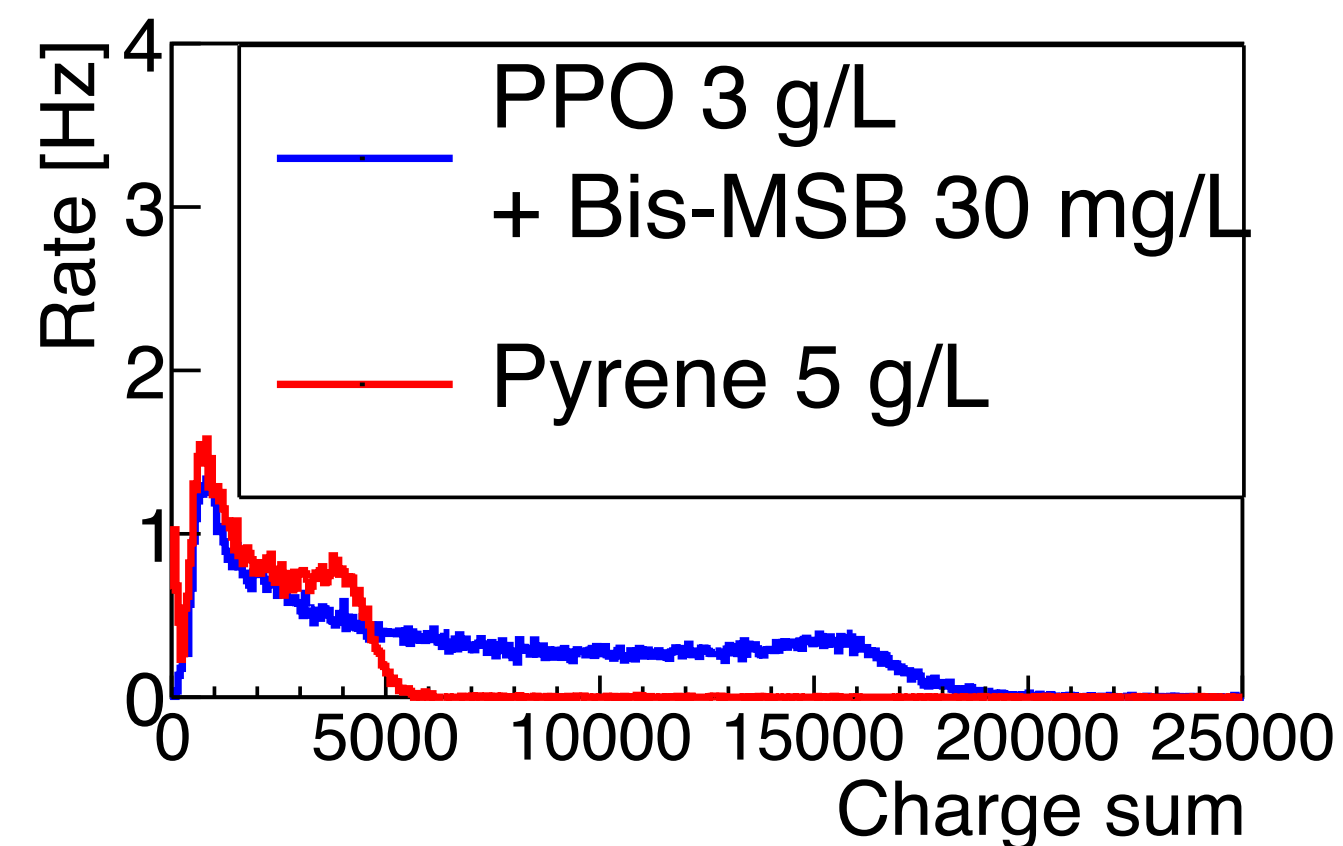


Shape	Cylindrical	Spherical
Radius (m)	7	7.25
Height (m)	14.5	-
Volume (m ³)	2232	1596
Mass (kg)	1920	1373
Number of PMTs	3700	3000

Size of buffer volume is under optimization.

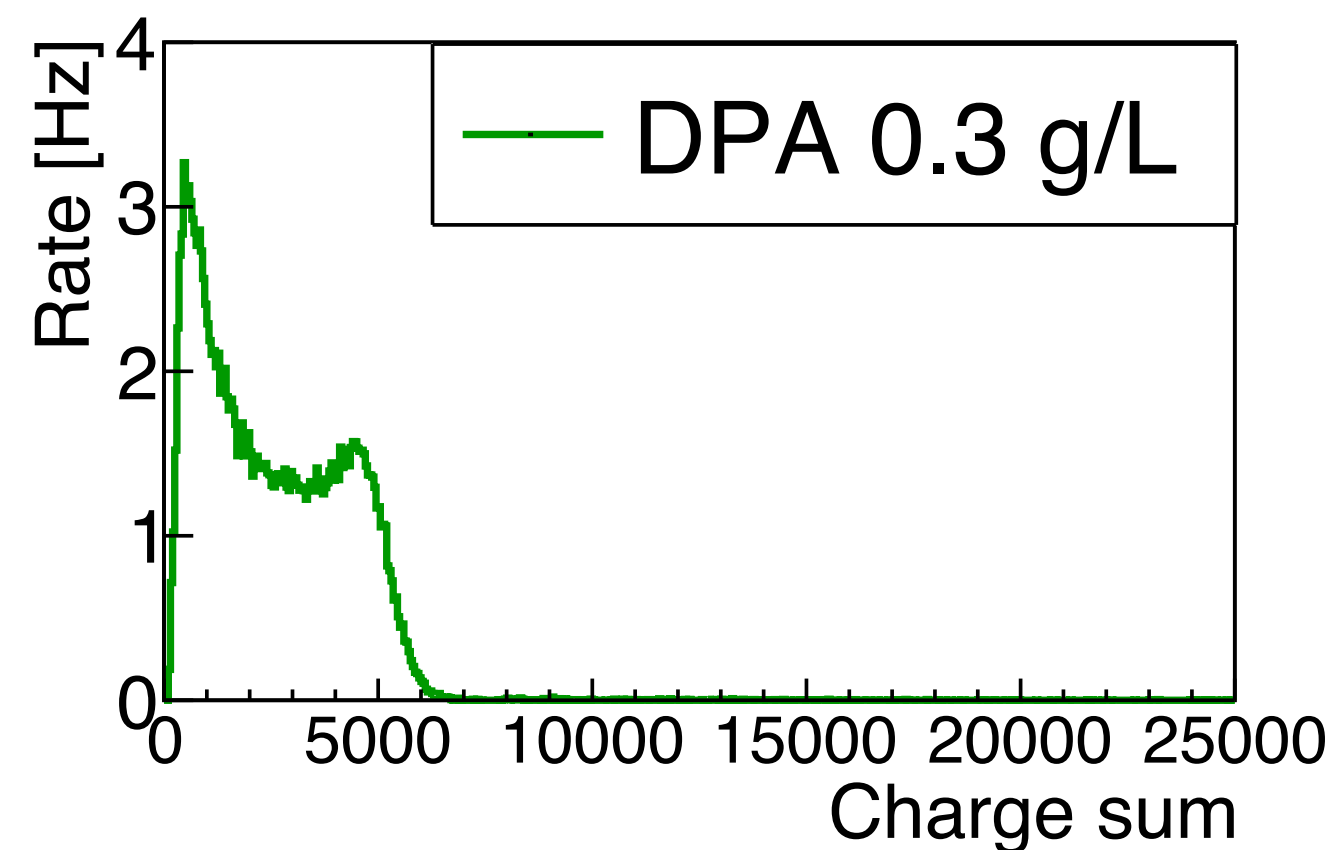
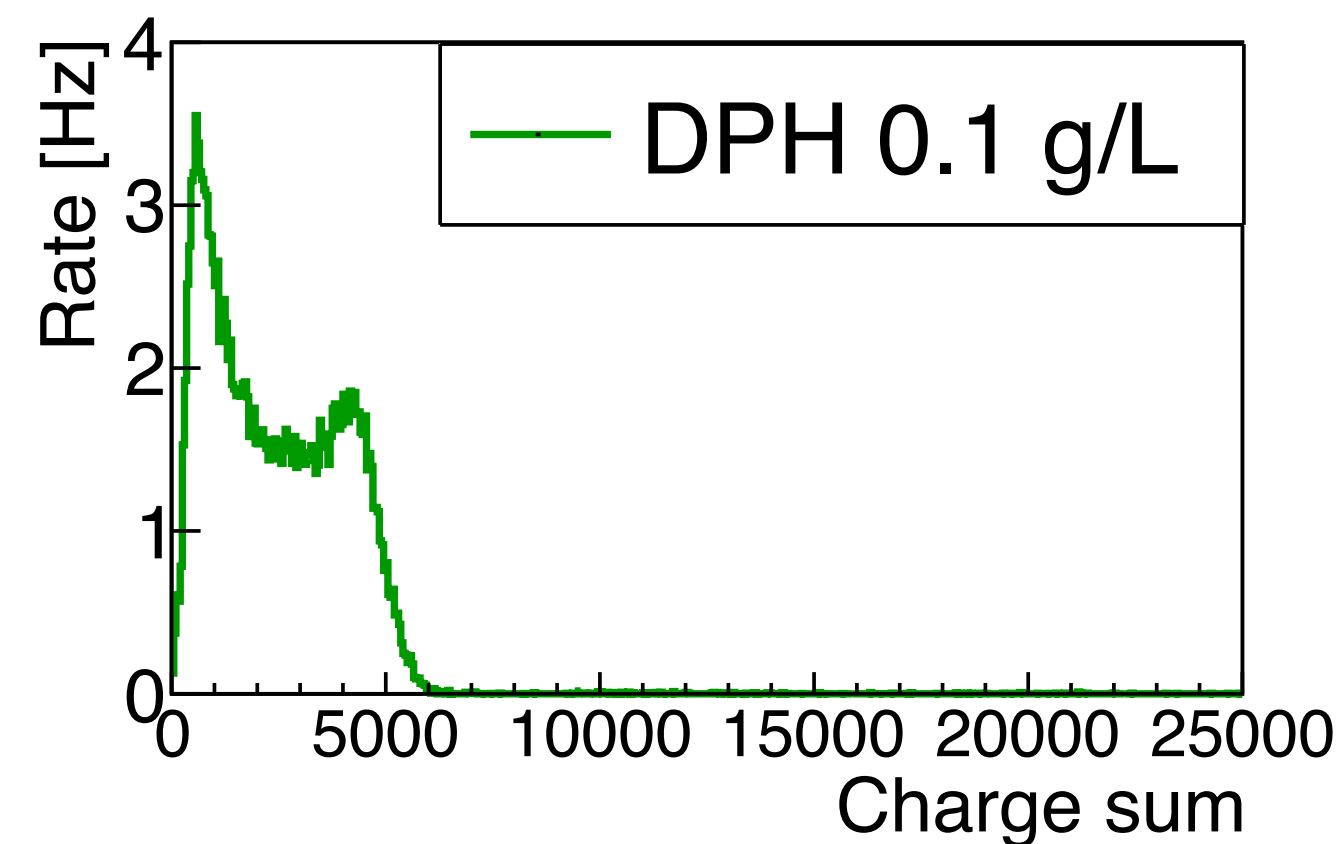
기본 검출기: 액체 섬광기

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>

광자검출기

우선적 선택은 **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.

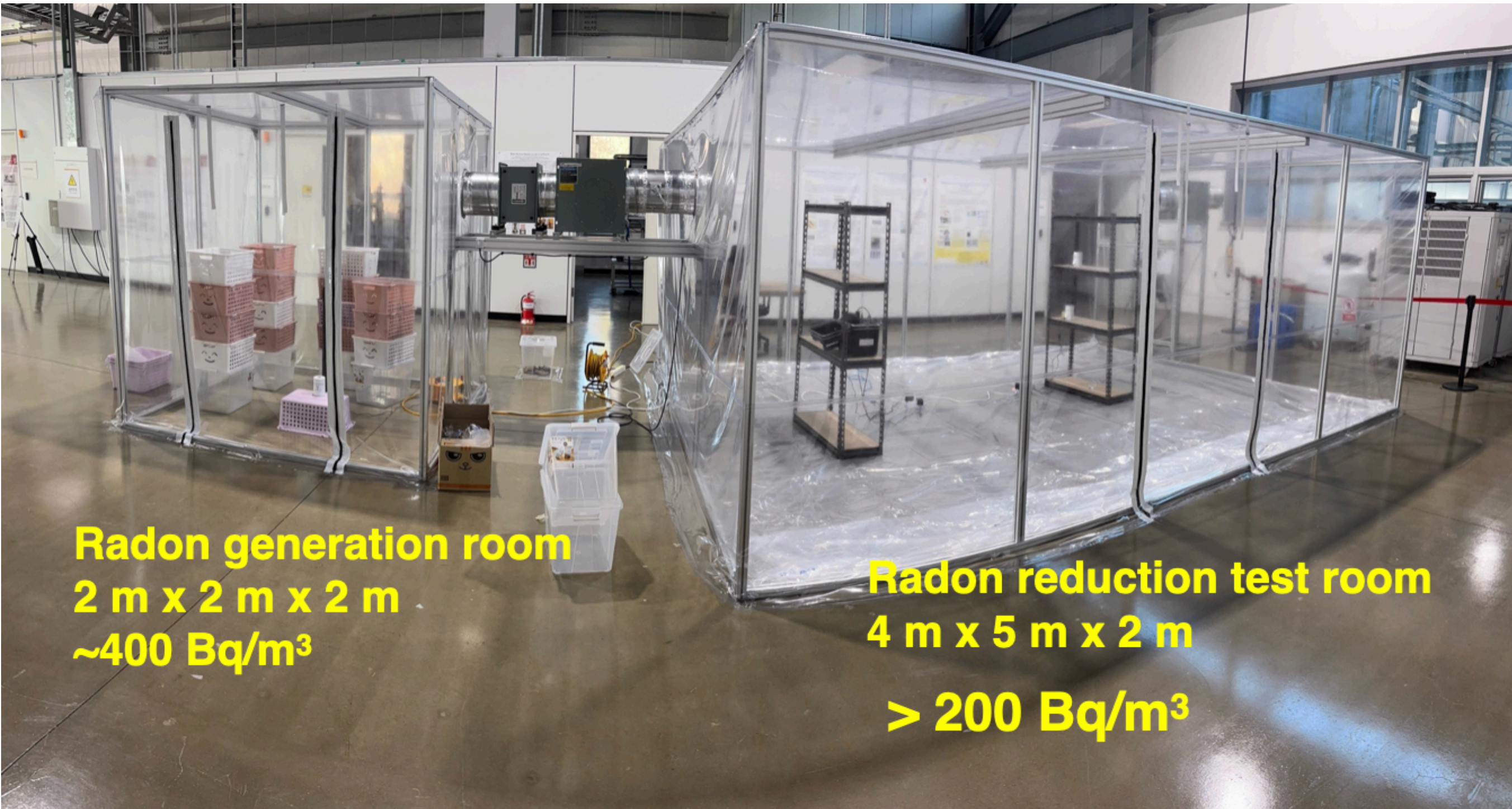
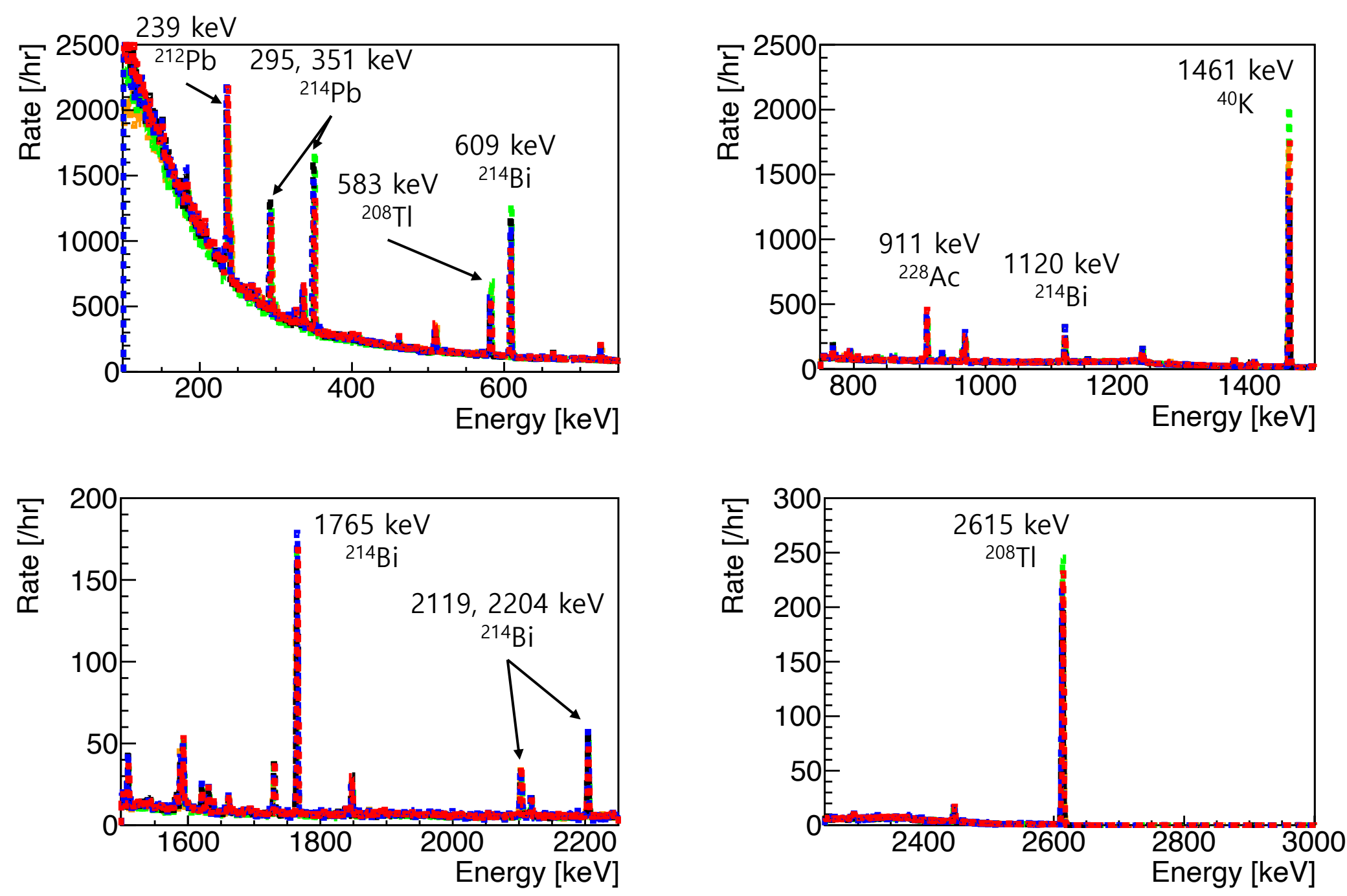
	Bq/kg		
	^{238}U	^{40}K	^{232}Th
Shotcrete	16.7 ± 0.6	447 ± 16	25.3 ± 0.6
Rock # 1	19 ± 2	618 ± 69	22 ± 2
Rock # 2	18 ± 2	872 ± 98	26 ± 2
Rock # 3	13 ± 1	561 ± 63	15 ± 1

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

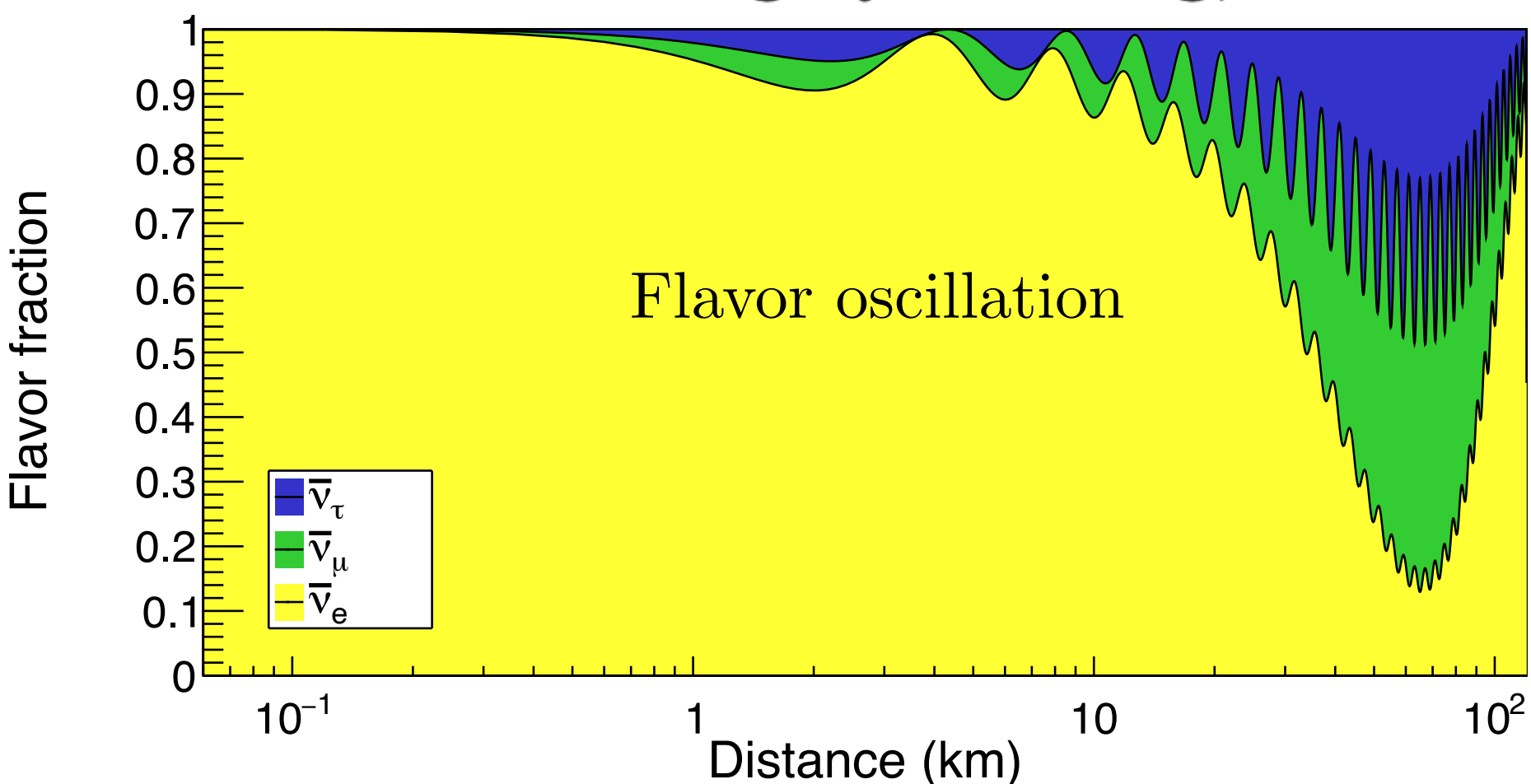
Radon reduction test room
4 m x 5 m x 2 m
> 200 Bq/m³

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

ν Oscillation

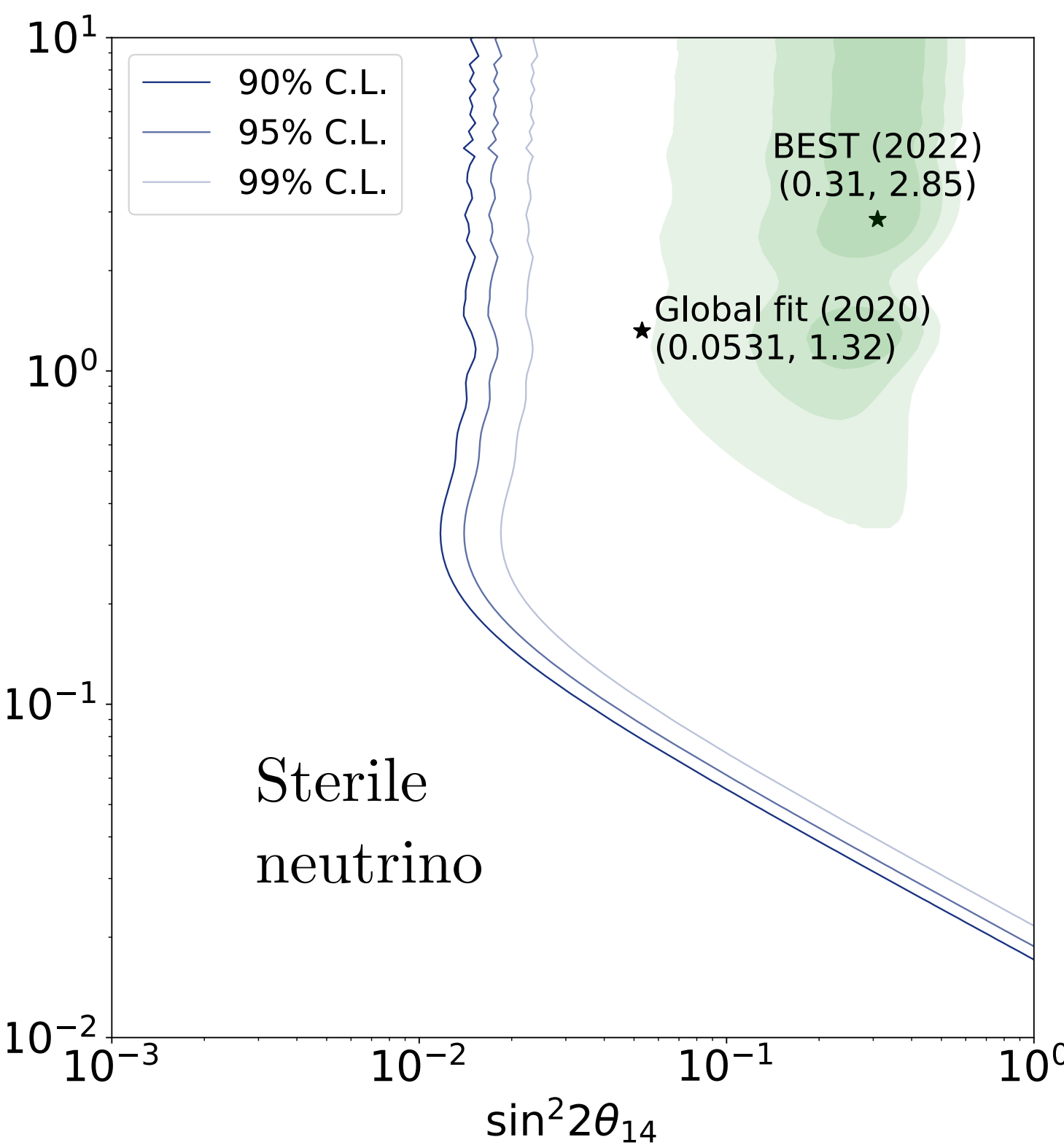
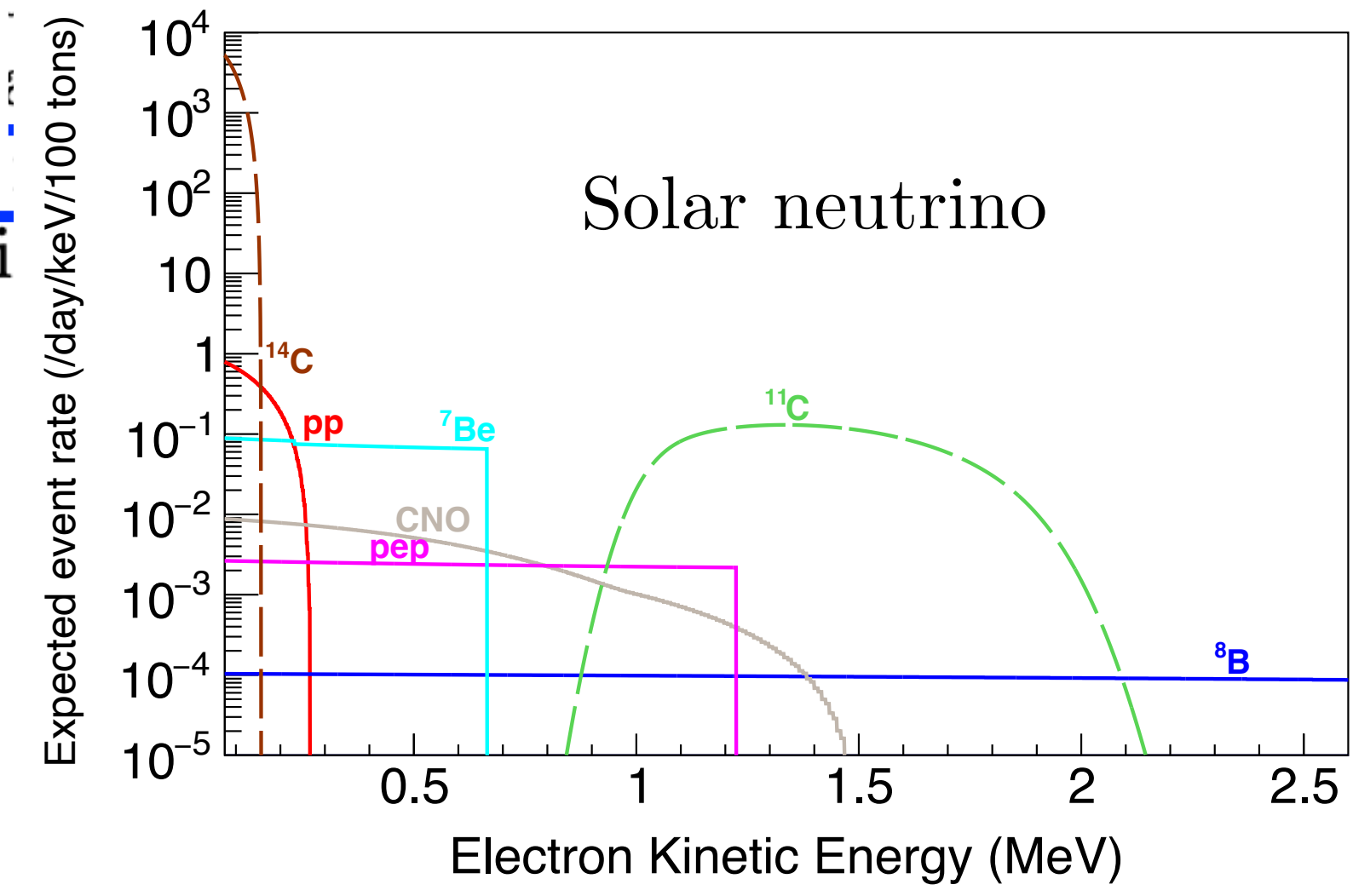
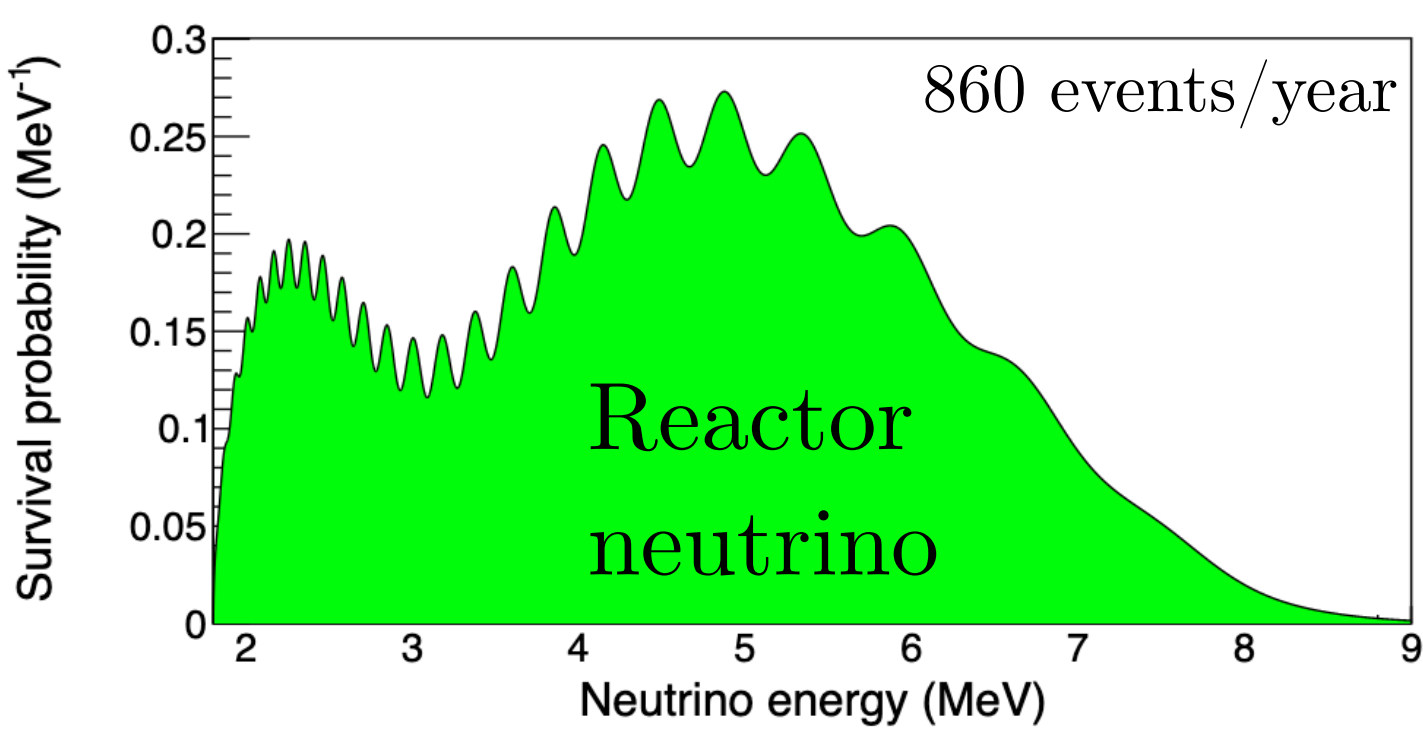
Seong-hyeok Jang,¹ Eun-Ju Jeon,² Youngju Ko,² Kyungmin Lee,¹ and Eunil Won¹

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.

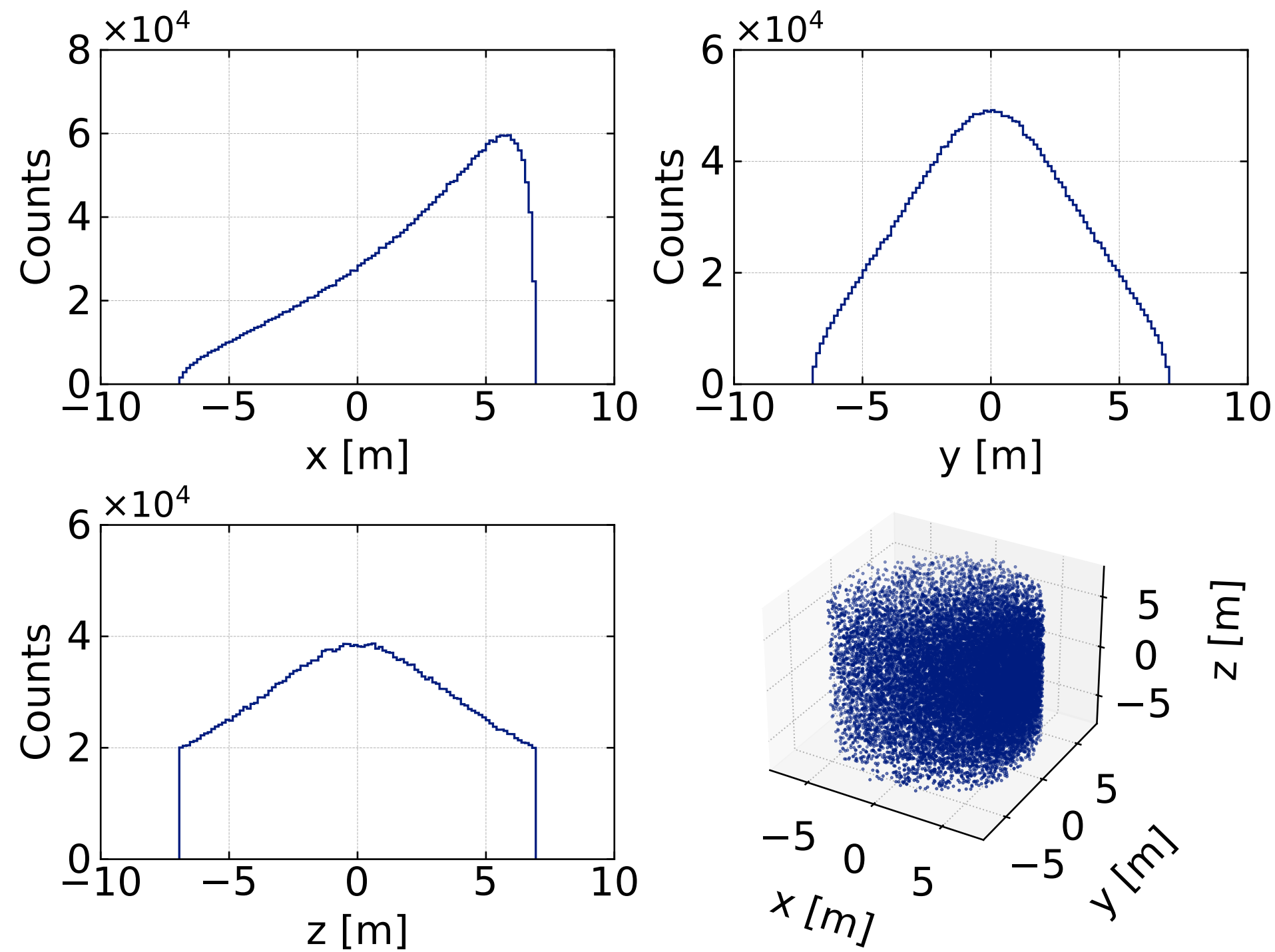
only phenomenon that cannot be explained by sterile neutrino interactions observed in ongoing or planned neutrino experiments. In this work, we develop a software package



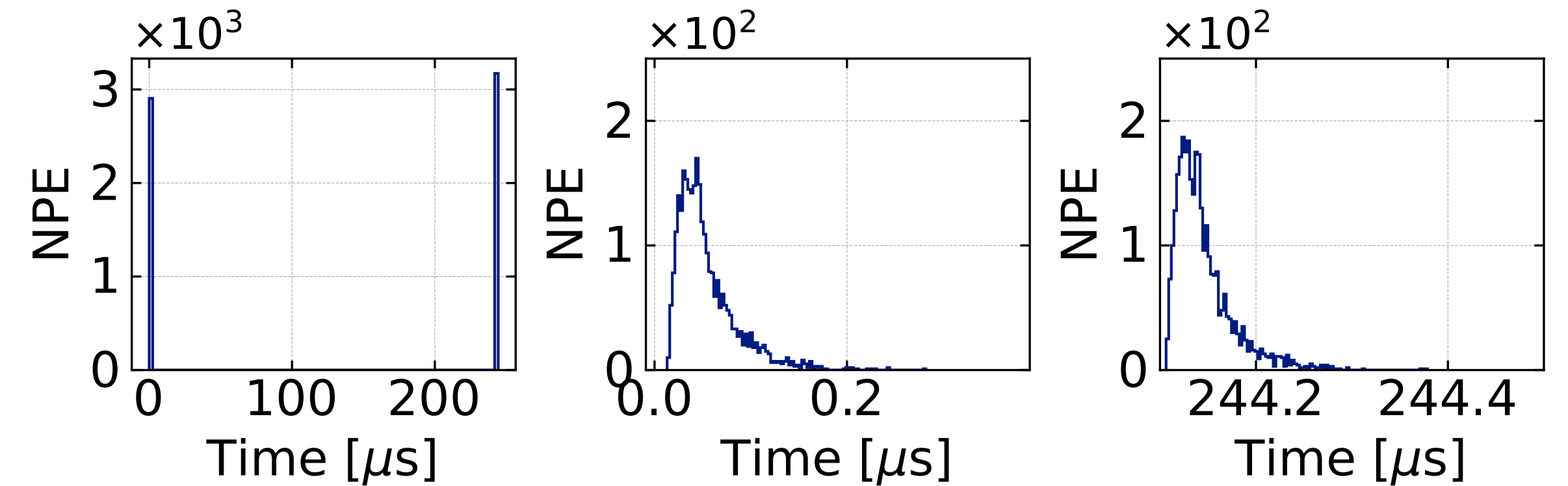
진동 소프트웨어 + 검출기 시뮬레이션 (Geant4)

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

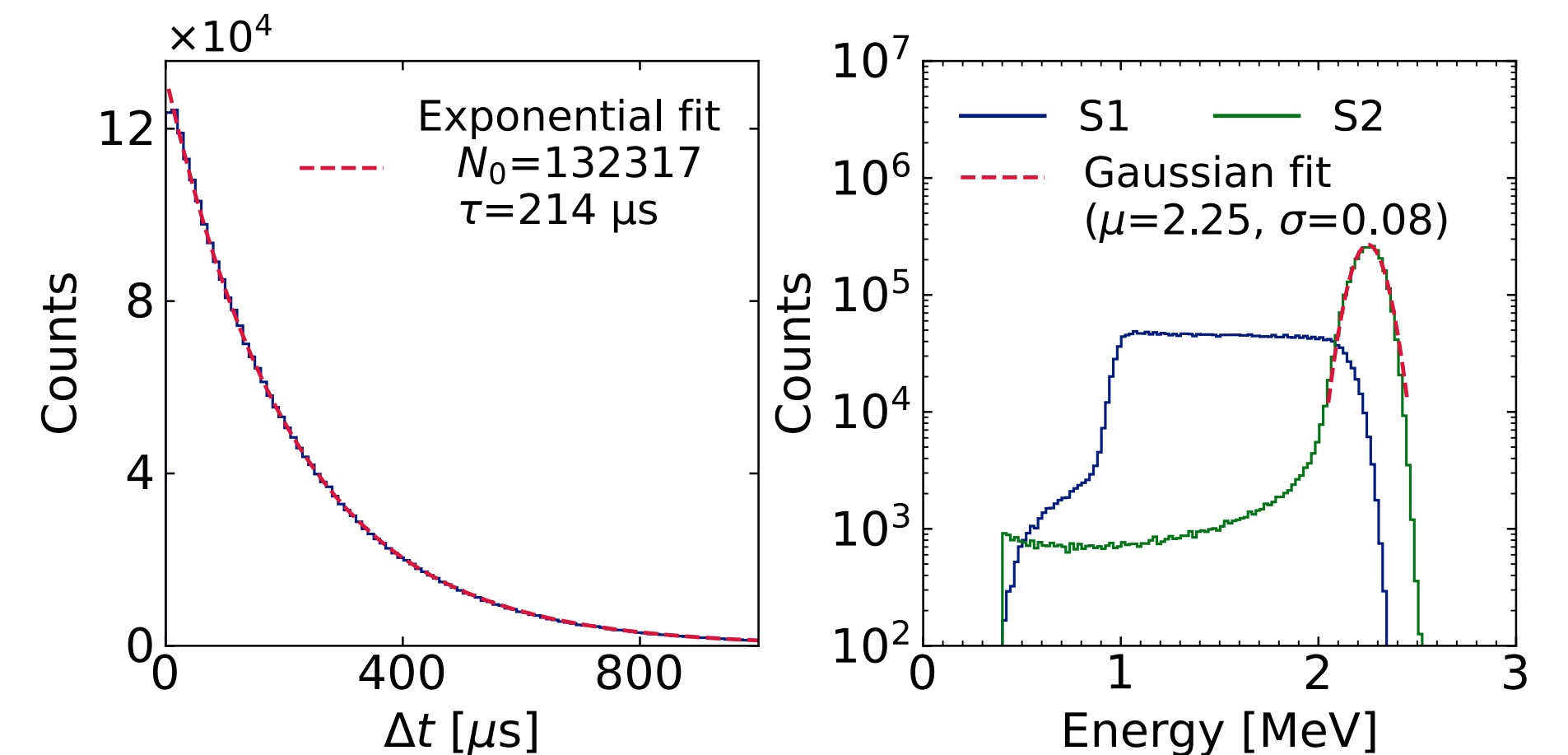
^{144}Ce at (9,0,0) m



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)

1 톤 뉴아이 시제품

부피 : 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. 르노 PMT 재사용 (RENO 분들께 감사합니다).

DAQ and HV

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

CAEN A7435SP (some parts have to be purchased).

목적

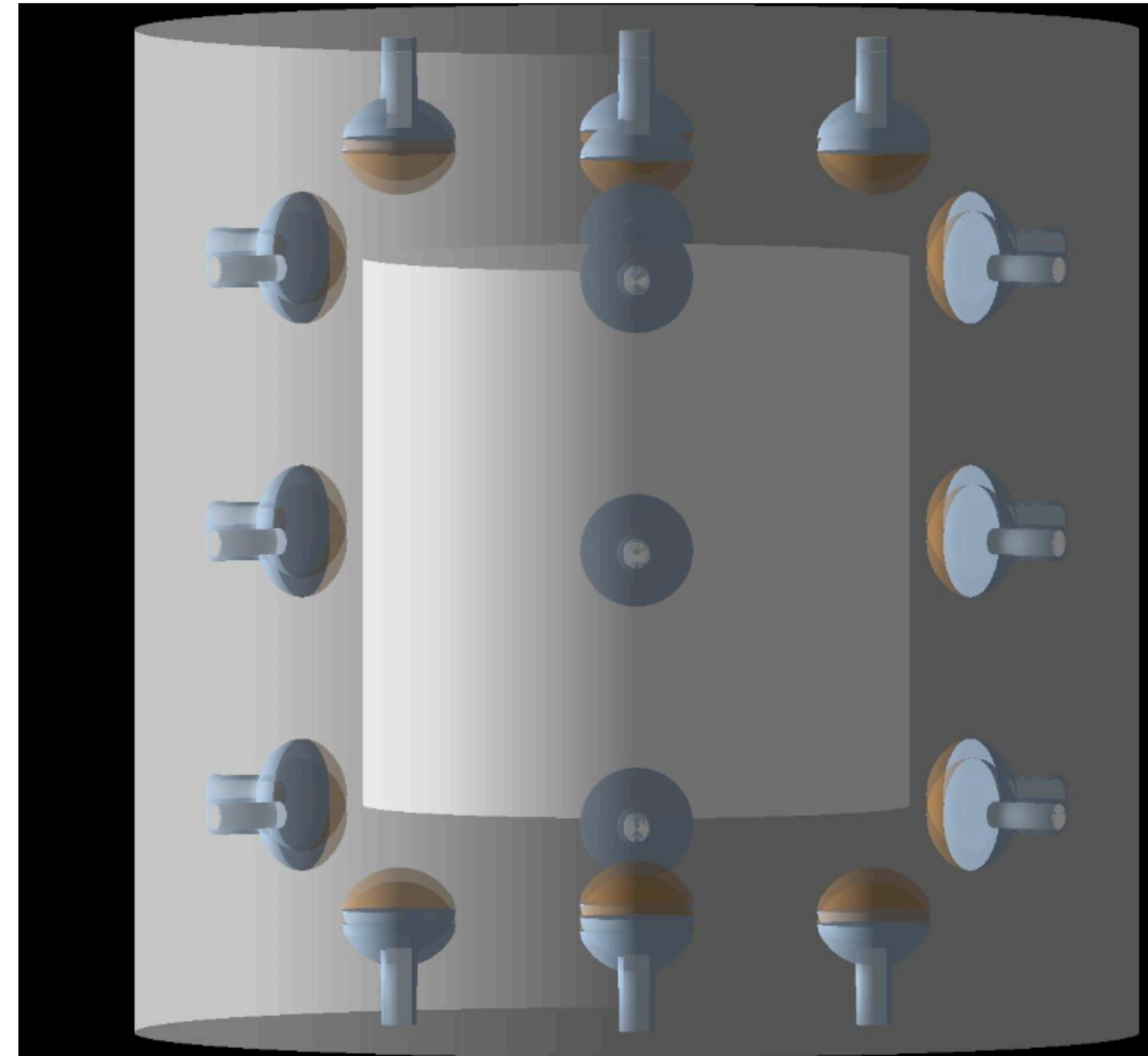
Study and optimize LS.

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.

올해 여름부터 시작



천막에서 시제품 실험 @ 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



Now @ Yemilab

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

Nitrogen gas stripping

Remove dissolved gases



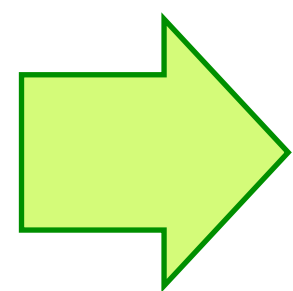
다른 개념의 검출기 가능성 연구

물 기반 (WbLS) Technique

전남대학교 (권순우 박사님), 중앙대학교

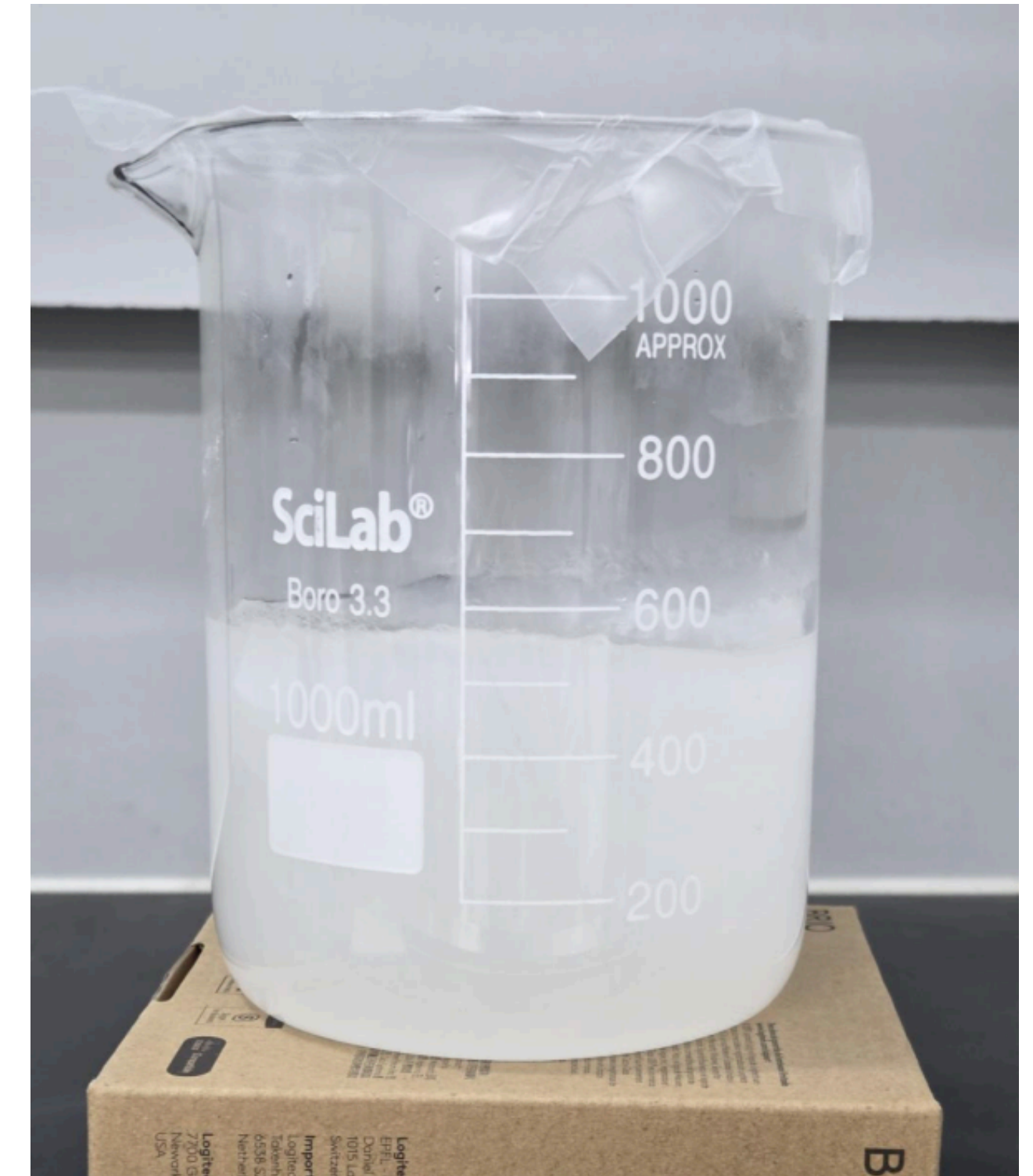
불투명 액체 섬광기 기술 (LiquidO)

- 신개념: 불투명 액체 섬광기
- 광자가 극소적으로 분포 (Rayleigh, Mie scatterings)
- 광섬유와 SiPM 으로 신호 읽기.



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.



Segmentation + ^{115}In loading ?

CDR 준비

CDR 준비 상황

- 뉴아이 프로젝트를 정부에 제안하기 위한 문서.
- 저희들끼리 소통 필요.
- 2025년 11월 말에 첫 버전 아카이브에 발간 목표.

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CDR authorship as of today.

The ν EYE Neutrino Telescope Conceptual Design I

Thank you all for
your support!

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V.I. Tretyak ^{22,23}, and Steve Elliott ²⁴

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

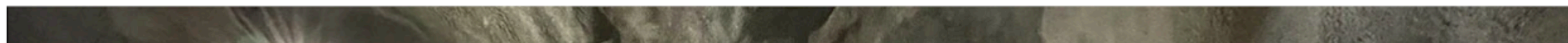
In September 2022, a new underground laboratory, [Yemilab](#), was completed in Jeongseon, Gangwon Province in South Korea, with a depth of 1,000 m. In the laboratory, the largest site is the LSC Hall, combining a square dome measuring 22 m (width) by 22 m (length) by 8 m (height) on top, with a cylindrical 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](#)



정리

뉴아이 중성미자 망원경: 다목적 2 킬로톤 액체 섬광 검출기 제안 (여미랩)

일부 주요 물리학 주제 논의.

- 비활성 중성미자 탐색.
- 태양 중성미자: “up-turn” in the survival probability, metallicity (not discussed).
- 원자로 중성미자: Yemilab is at the first minimum of Hanul reactor.

뉴아이 기본 설계 계획 설명 .

- 액체 섬광기: slow LS.
- PMT: 8 inch version + light concentrator (for now at least).
- 더 좋은 방법 가능성 고민 중.

올 여름 부터 1 톤 검출기 제작 중: **인원 부족**: 도와 주시면 감사드리겠습니다.

후학들을 위한 본 프로젝트 제안에 많은 관심을 가져 주시면 감사드리겠습니다.