CENTER FOR UNDERGROUND PHYSICS

ICECUBE
SOUTH POLE NEUTRINO OBSERVATORY

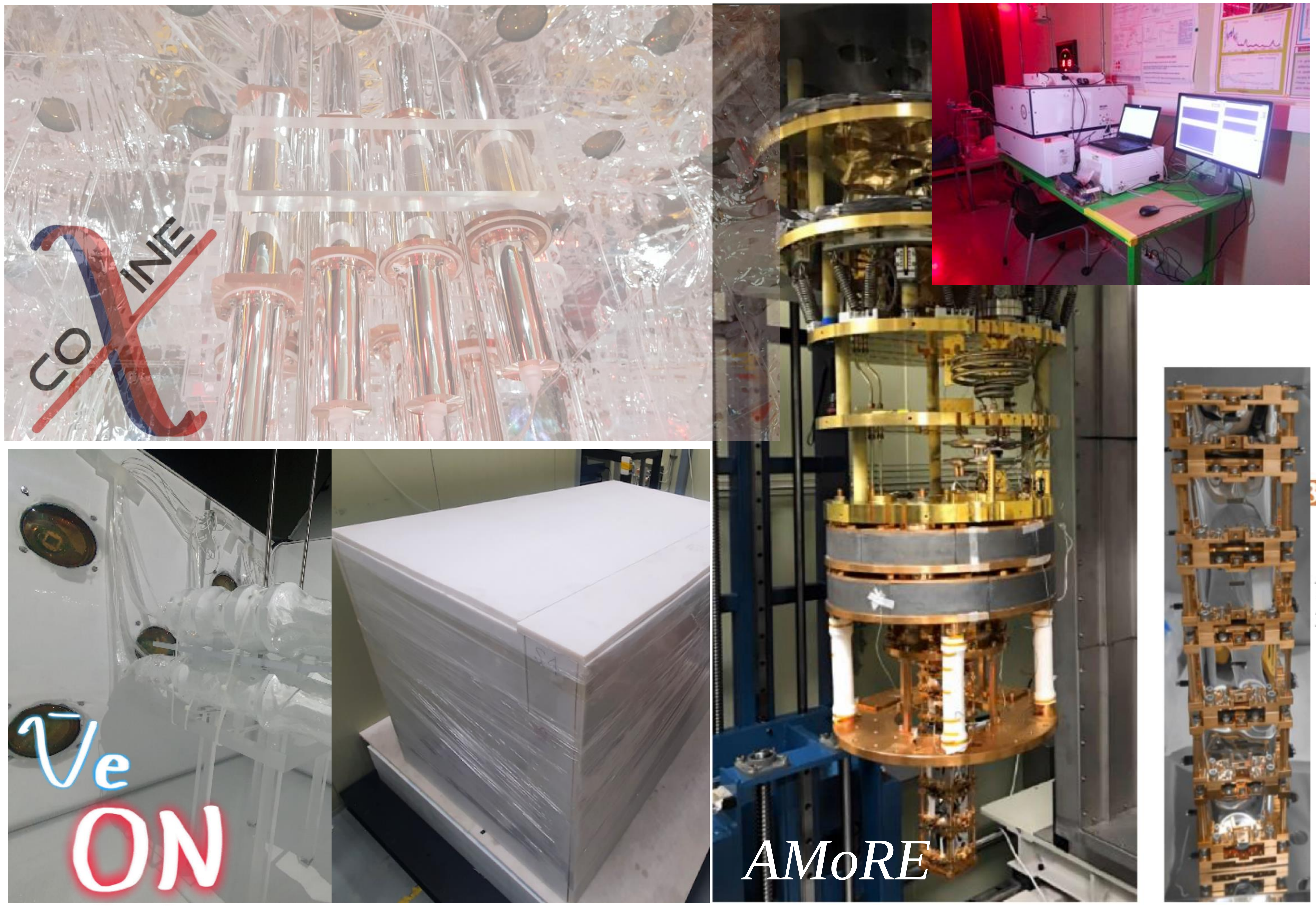
Rare Event Search Lab. Activities 2023

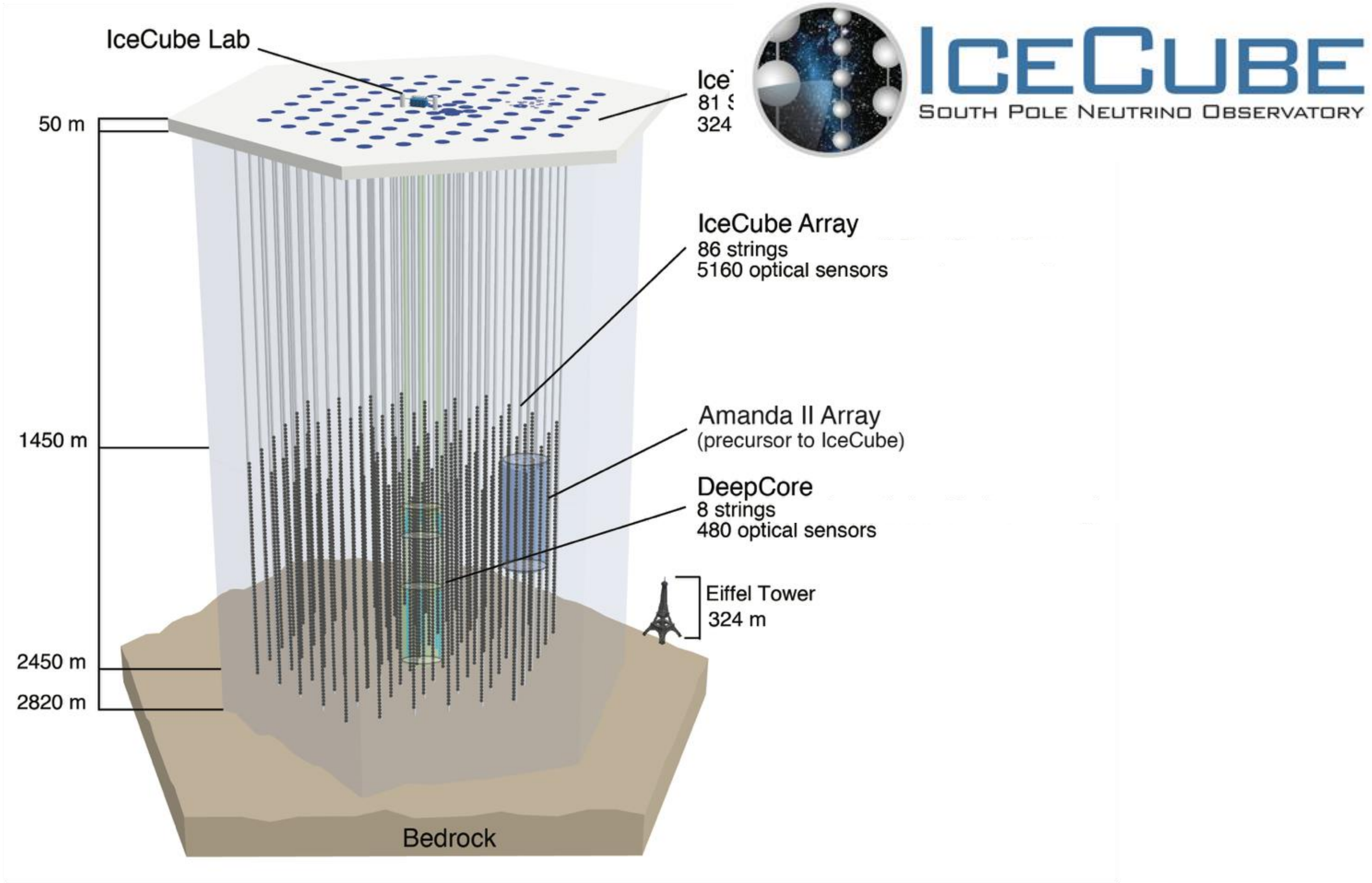
Ha, Chang Hyon
Dept. of Physics, Chung-Ang University
December 27, 2023

FOUR BrainKorea21
준입자 및 기본입자 물리연구팀

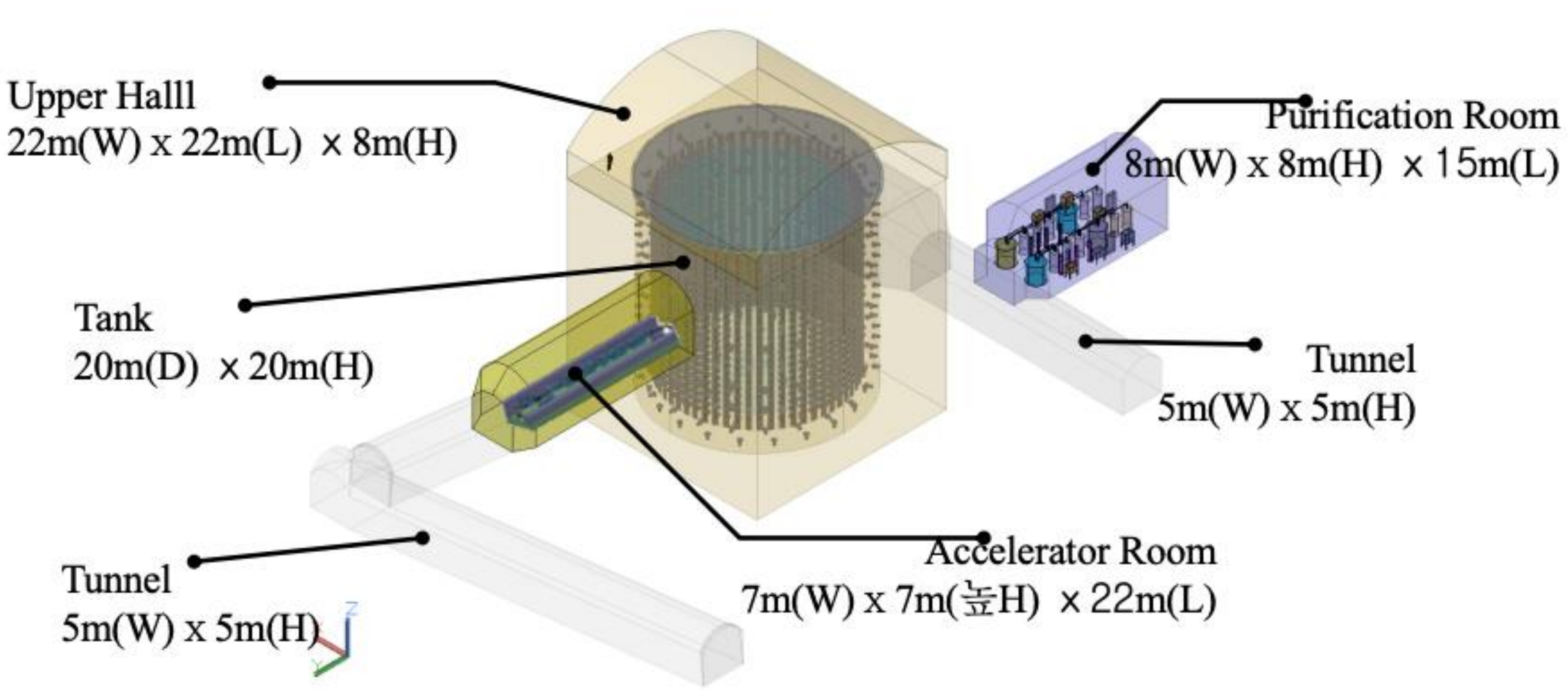
RESL
RARE EVENT SEARCH LABORATORY

A Vision for Dark Matter and Neutrino physics in Korea





Large Scintillator Counter (LSC)



Group

- Chang Hyon Ha: Metal-loaded Liquid scintillator R&D (LSC)
- Jinyoung Kim: Neutron & Dark Matter Annual Modulation (COSINE)
- Yujin Lee: Phoswich—>Pulse-shape discrimination of Dark Matter nuclear recoil (COSINE)
- Byoung-cheol Koh: Neutrino-Nucleus Coherent Scattering (NEON)
- Jong Seok Chung: Cryogenic detection of rare nuclear events (AMoRE)
- HanI KimKu: CANDY—> IceCube-DeepCore data analysis (IceCube)
- Seong Joon Won: High-purity Germanium detector development (HPGe)
- Jiwon Seo : Position-sensitive detector development (HAWL)
- JoonBomb Lee : AMoRE software development (AMoRE)

Research

- Hardware R&D
  - Position-sensitive Scintillator development
  - Multi-channel DAQ system
  - Improving scintillator Light yield
  - Metal doping into Liquid scintillator
  - Experimental support
- Software Analysis
  - ROOT, GEANT4, Python
  - LLH methods and Bayesian Methods for parameter inference.
  - Machine Learning and Deep Neural Network for discrimination and reconstruction.
- Other
  - Education-based muon detector development.

Publications in Progress

Submitted to Frontiers

frontiers

Pulse shape discrimination in an organic scintillation phoswich detector using machine learning techniques

Yujin Lee[1], Jinyoung Kim[1,*], Byung-cheol Koh[1], Young Soo Yoon[2], and Chang Hyon Ha[1,*]

PEPV & Electron stability draft in progress

PREPARED FOR SUBMISSION TO JCAP

Tests for the electron stability and the Pauli Exclusion Principle with COSINE-100

X XXXX,[a] G. Adhikari,[b] N. Carlin,[c] J.J. Choi,[d] S. Choi,[d]

HAWL draft in progress

Hankuk Atmospheric-muon Wide Landscaping : HAWL

RESL[1]

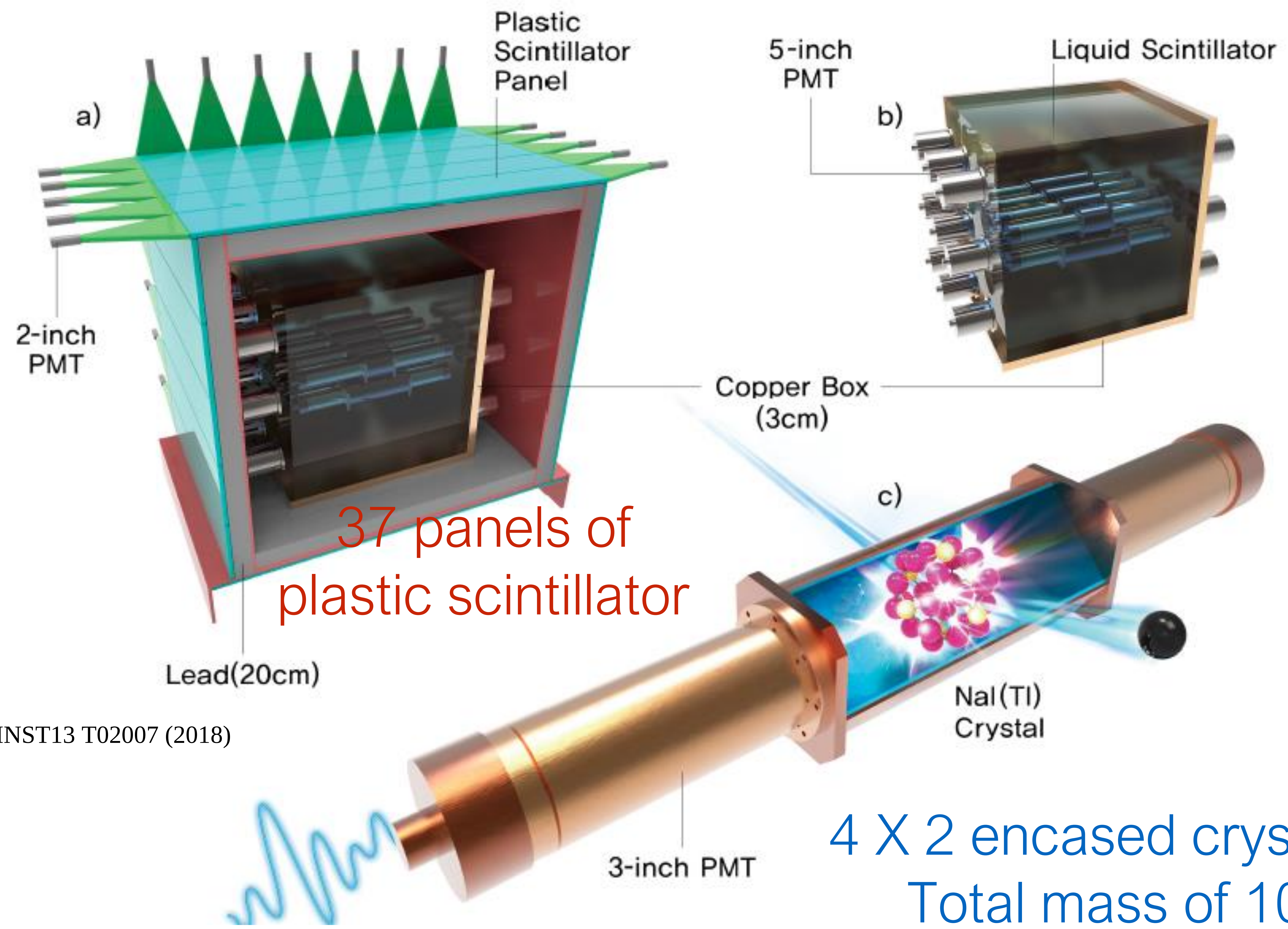
[1]*Department of Physics, Chung-Ang University, Seoul 06973, Republic of Korea*

Cosmic ray muons are useful in various fields from particle physics experiments to non-invasive tomography, thanks to their high flux and high penetrating capability. With a plastic scintillator panel detector installed in a car, we map the terrain of mountains above highway tunnels and underground spaces. Depth resolutions for the overburden are found to follow the $f(x)$ form which describes the event rate and speed of the vehicle.

INTRODUCTION

supporting the detector shape is made with a s
mm on each side for the space to connect the

The COSINE-100 detector

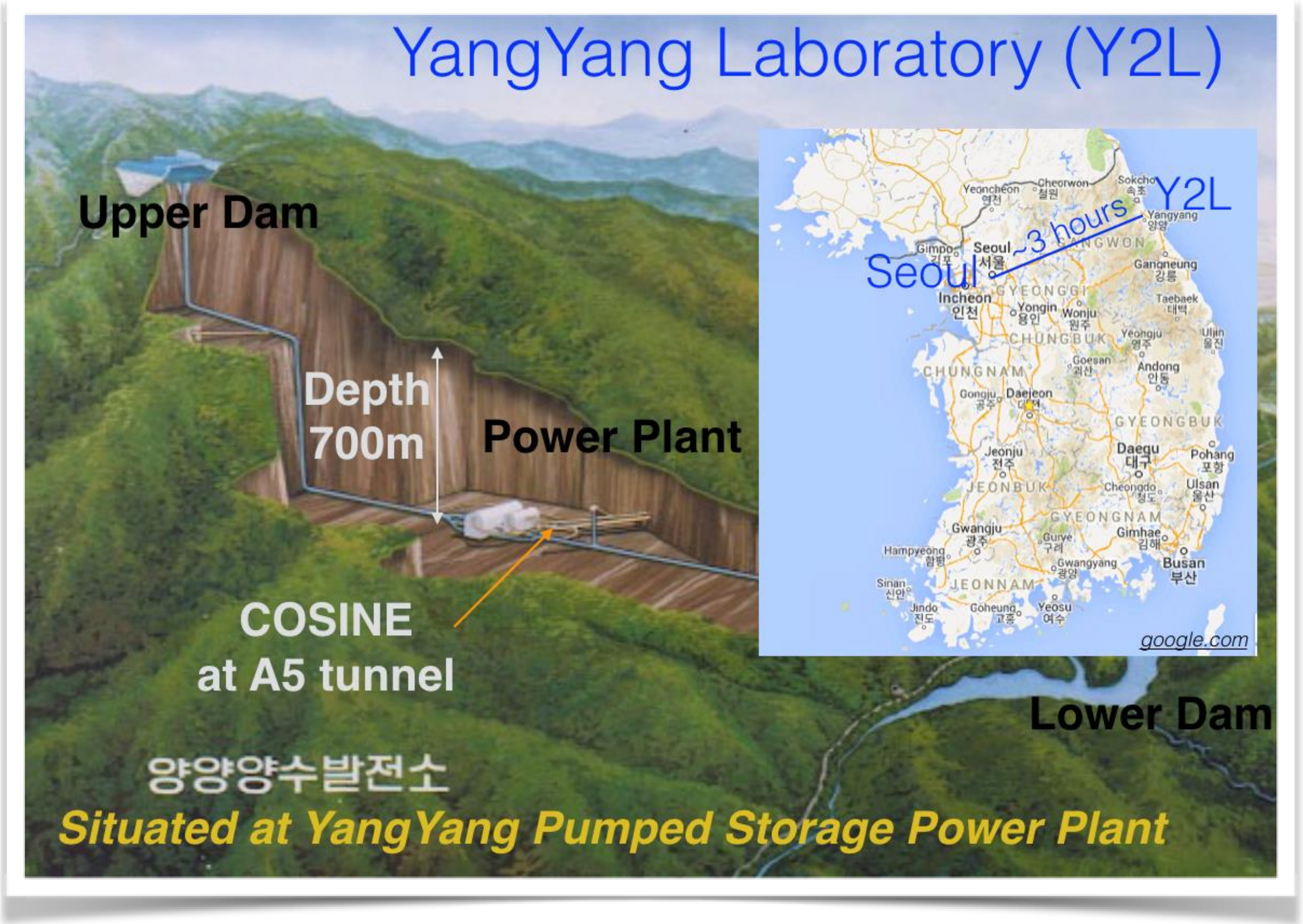


37 panels of plastic scintillator

JINST13 T02007 (2018)

2 tons of liquid scintillator

Nucl. Instrum. Meth. A 851 102 (2017)

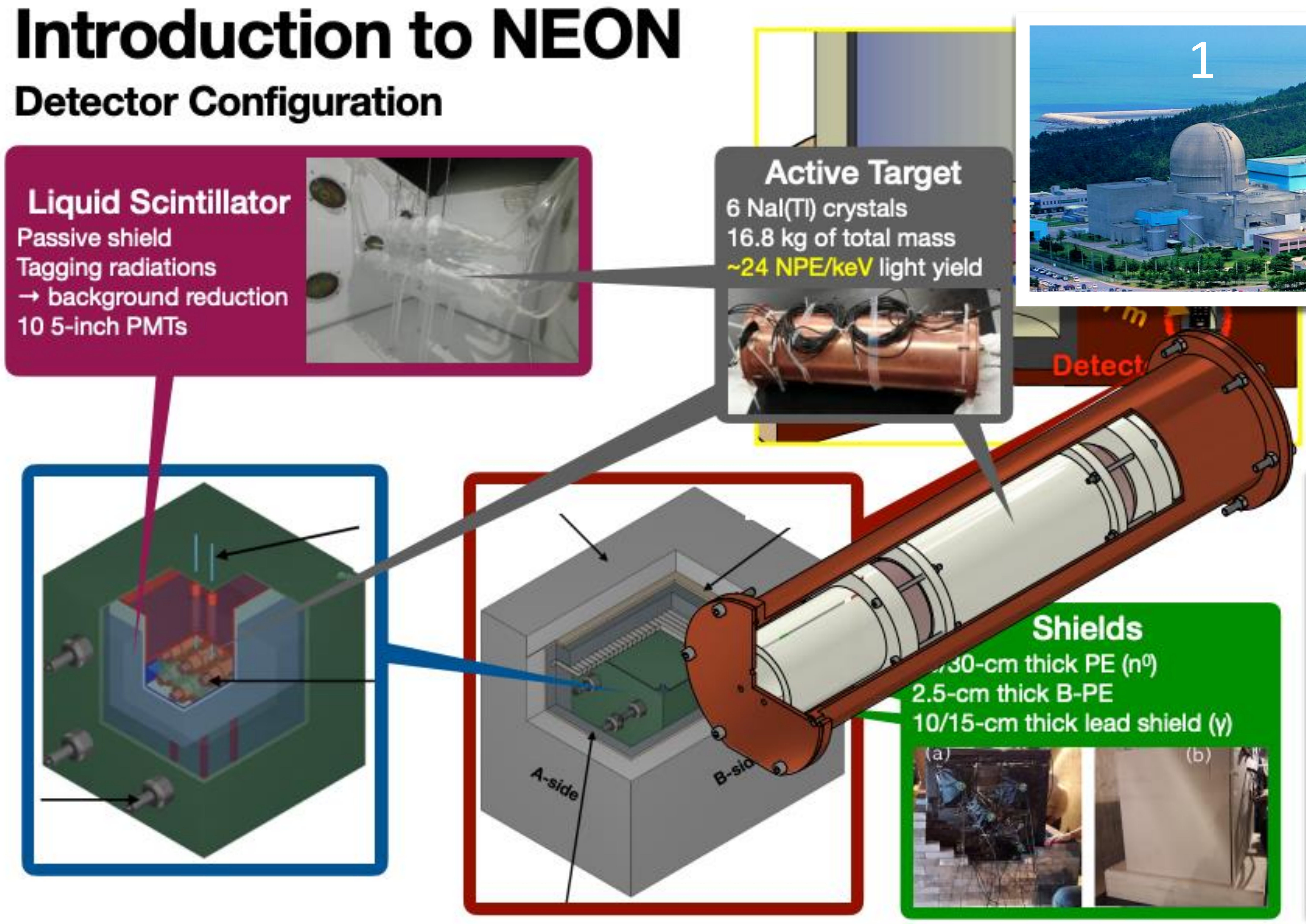


4 X 2 encased crystal array

Total mass of 106 kg

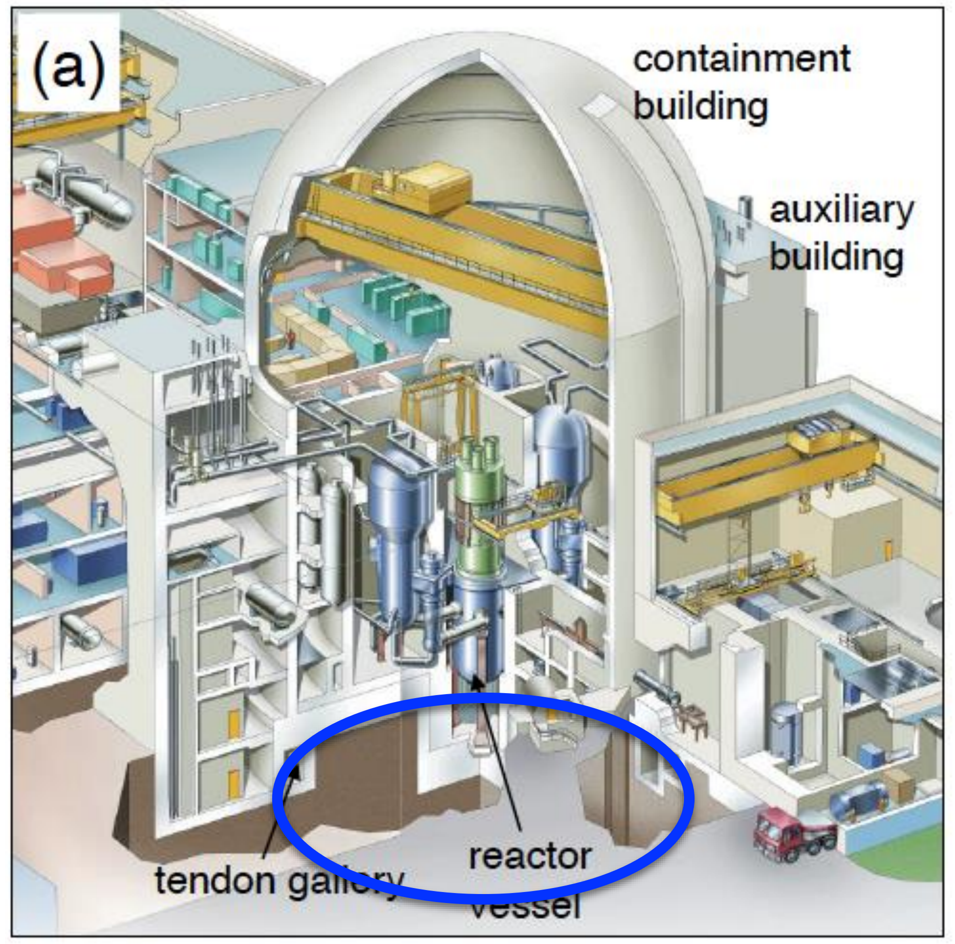
Eur. Phys. J. C. 78 107 (2018)

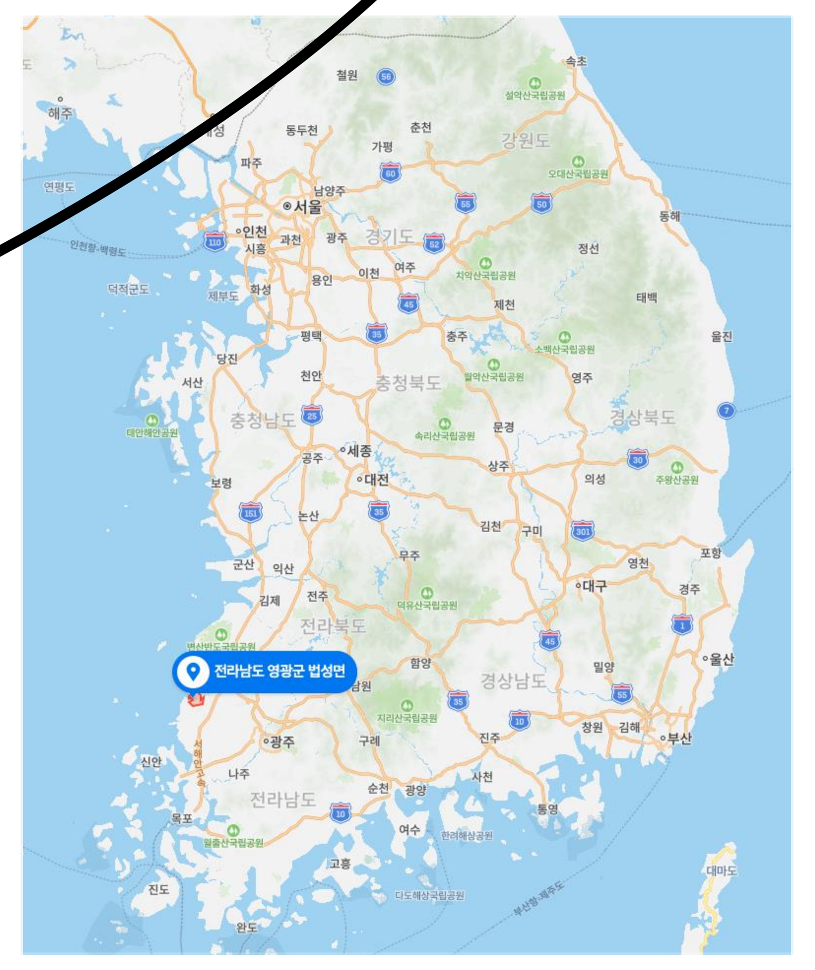
The NEON experiment



Hanbit Nuclear Power Plant (Yeonggwang)

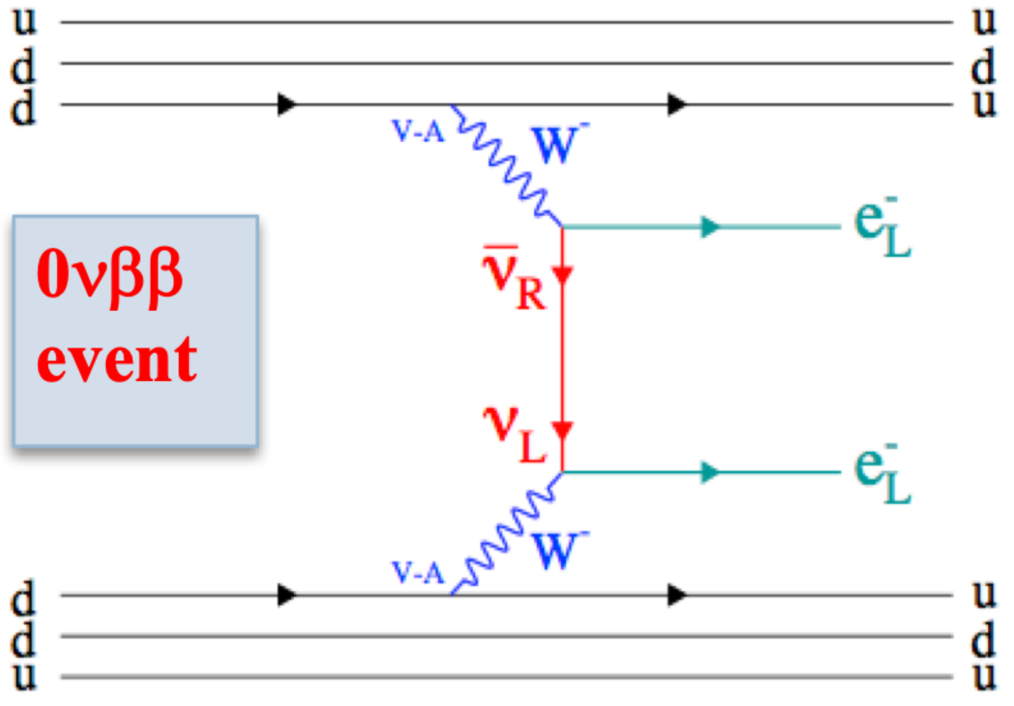
No. 6 Reactor

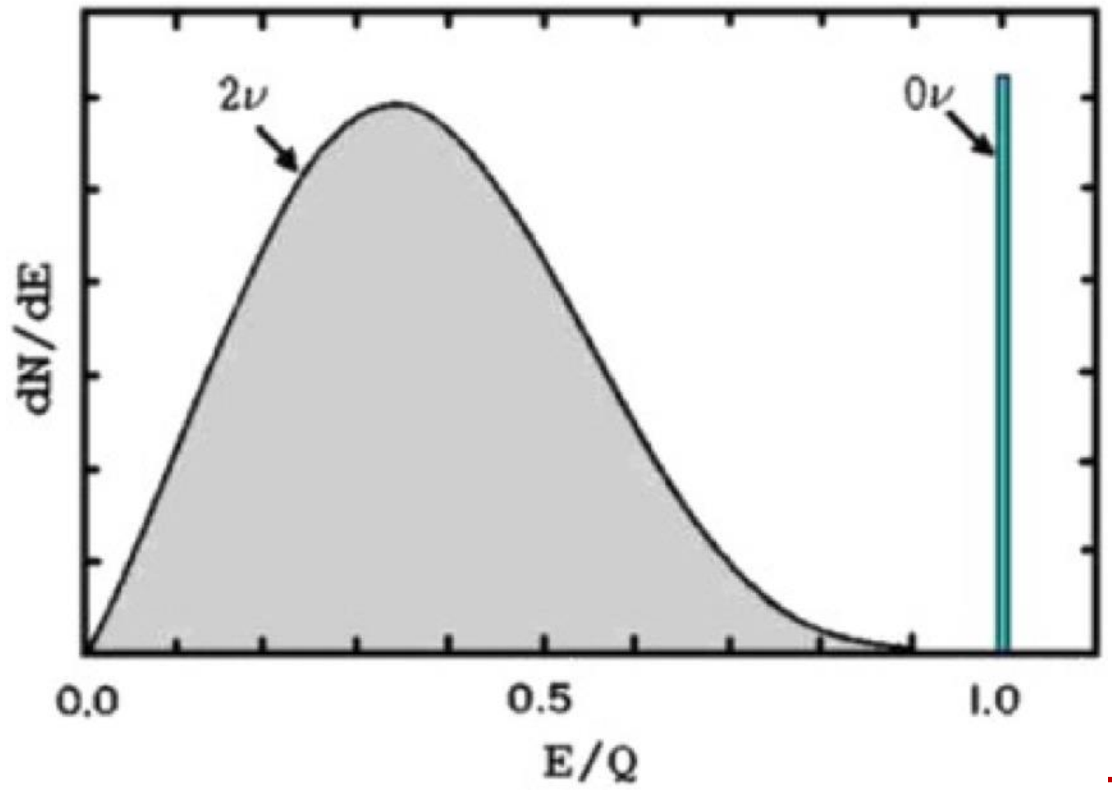




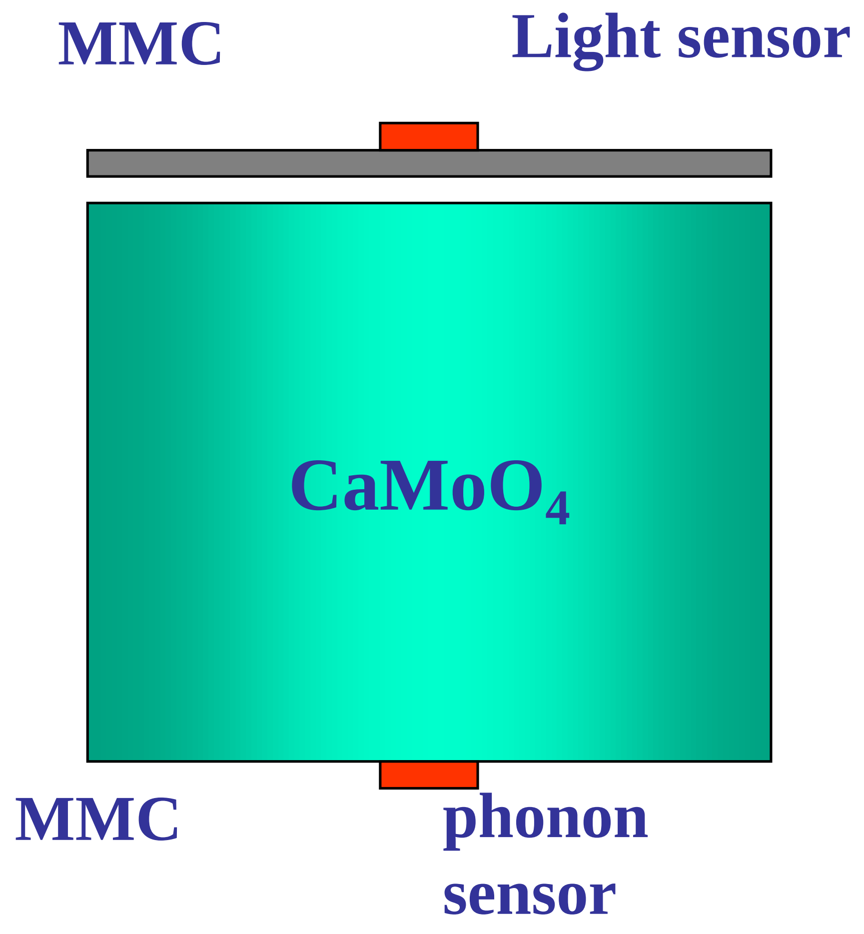
The AMoRE Experiment

- Purpose – Check further on detector performance & backgrounds.
- Upgrades from Pilot
  - **Add 7 more CMO($^{40}Ca^{100}MoO_4$)crystals and 5 LMO($Li_2{}^{100}MoO_4$) crystals.**
    - **13 CMO(4.6 kg) + 5 LMO(1.6 kg) → ~3 kg of ^{100}Mo**
  - Outer Pb shields 15 cm → 20 cm to decrease rock gamma backgrounds.
  - Add more neutron shields (boric acid+PE+b.PE)
  - MMC sensor upgrade (AuEr→AgEr)
  - Capton PCB
  - SS screws → Copper or Brass screws.
  - Light Detector wafers are hard glued to holder.





Low Temp. Detector
Source = Detector



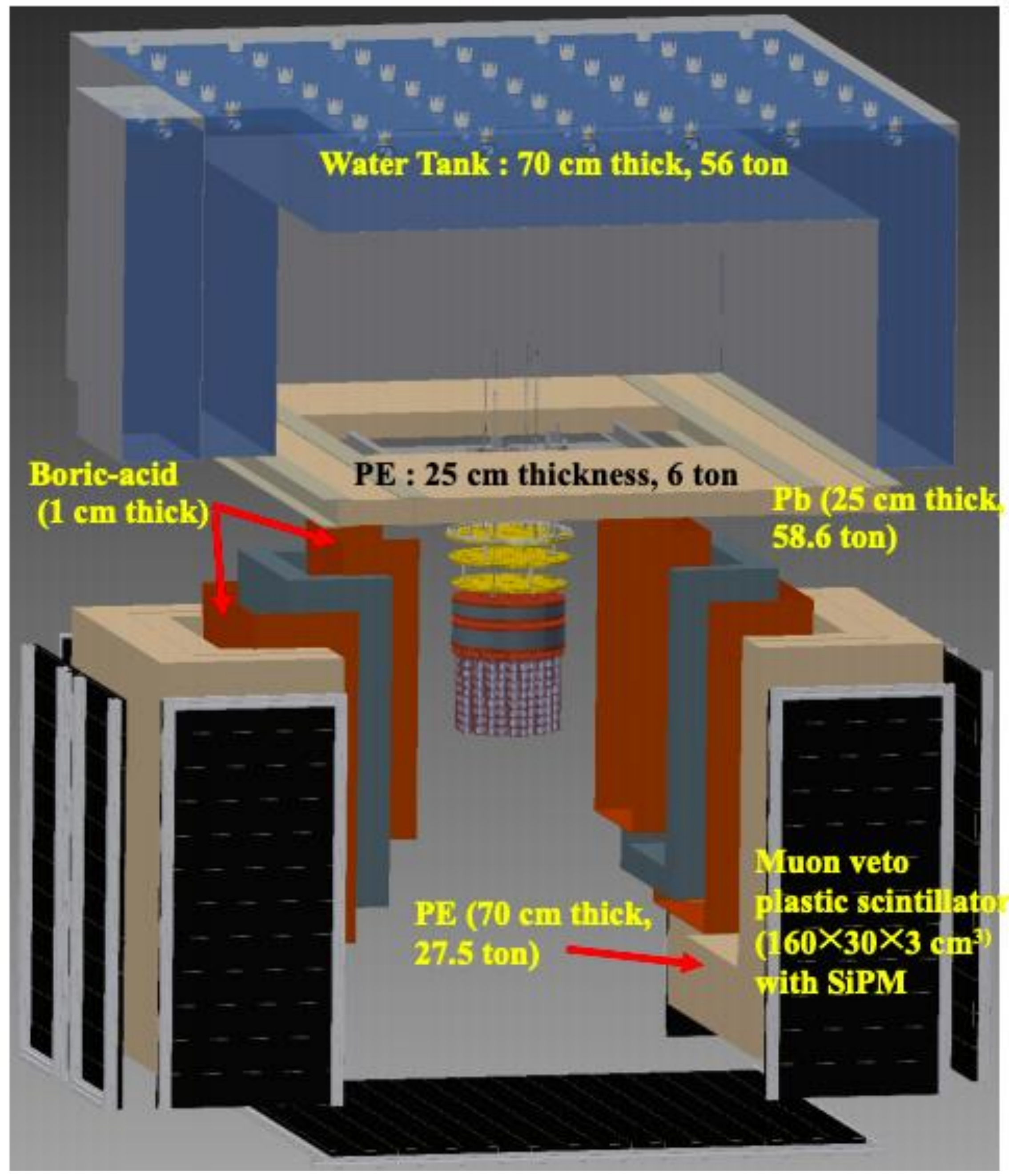
<10-50 mK>

$CaMoO_4$
- Scintillating crystal
- High Debye temperature:

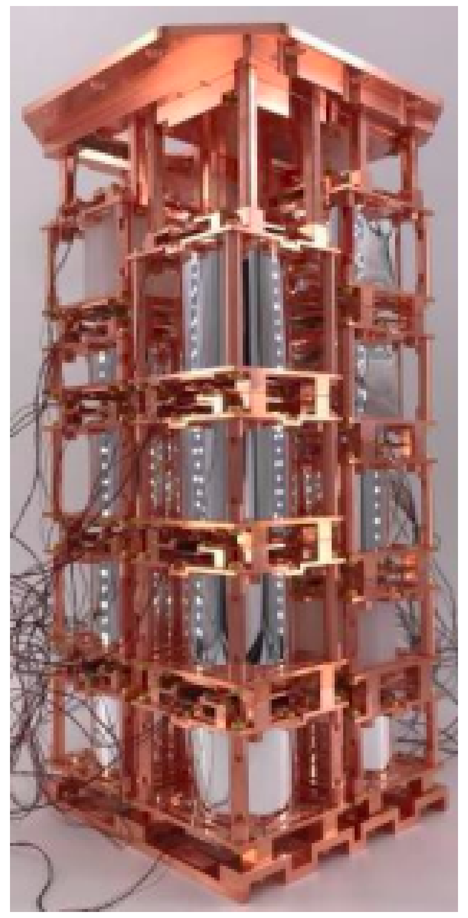
T_D = 438 K, $C \sim (T/T_D)^3$

- $^{40}Ca^{100}MoO_4$

MMC (Metallic Magnetic Calorimeter)
- Magnetic temperature sensor (Au:Er) + SQUID
- Sensitive low temperature detector with highest resolution
- Wide operating temperature
- Relatively fast signals
- Adjustable parameters in design and operation stages

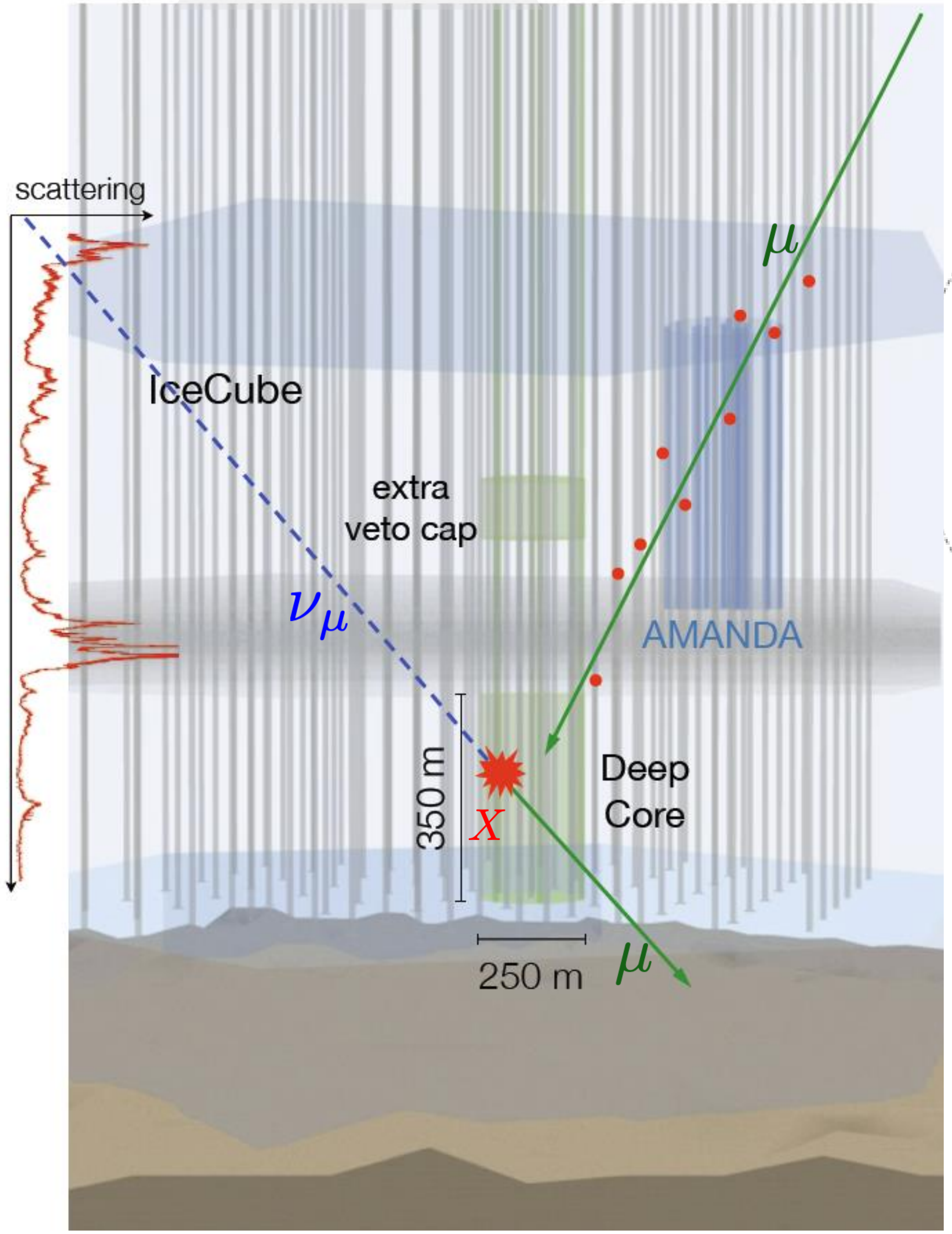


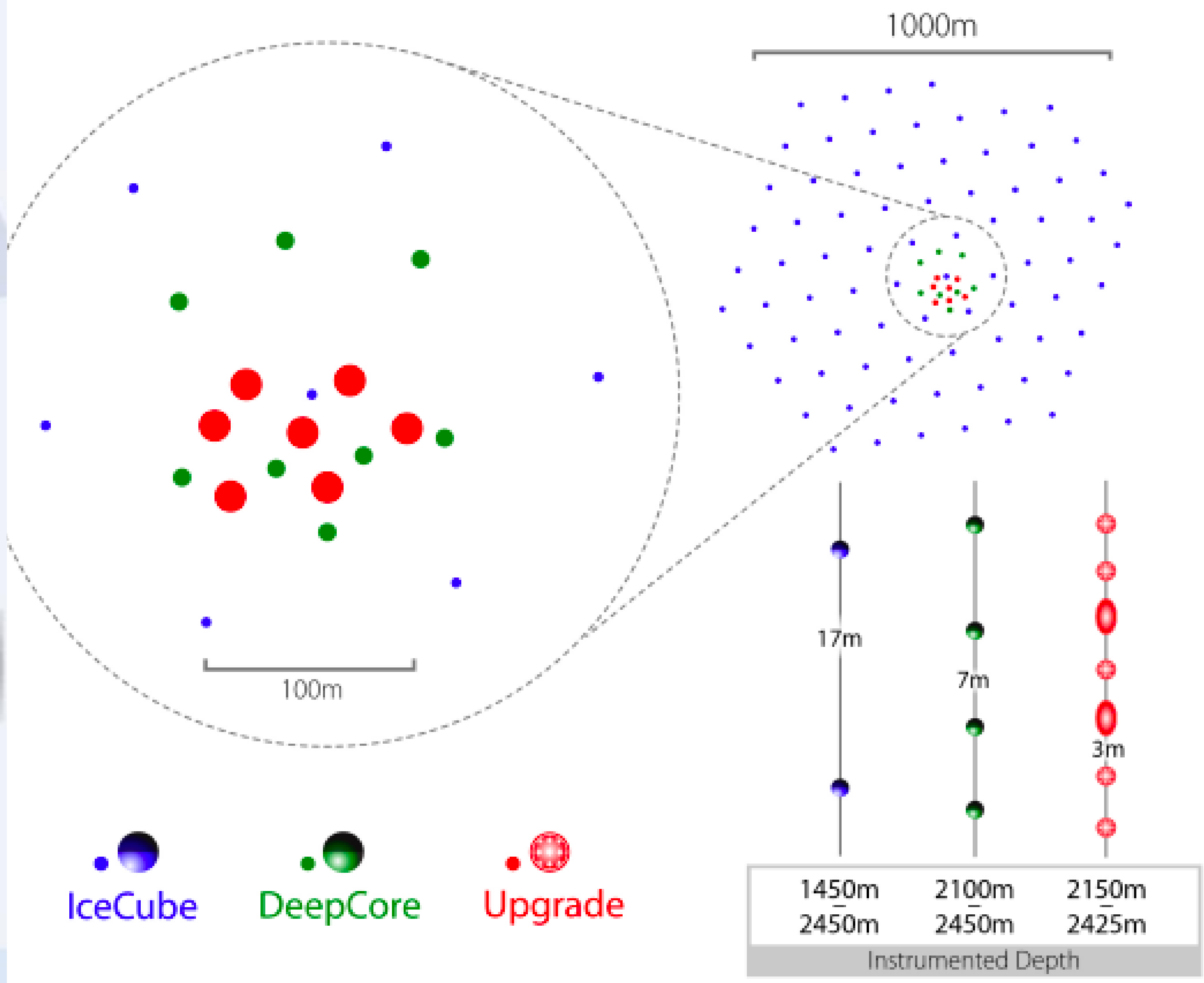
AMoRE-II

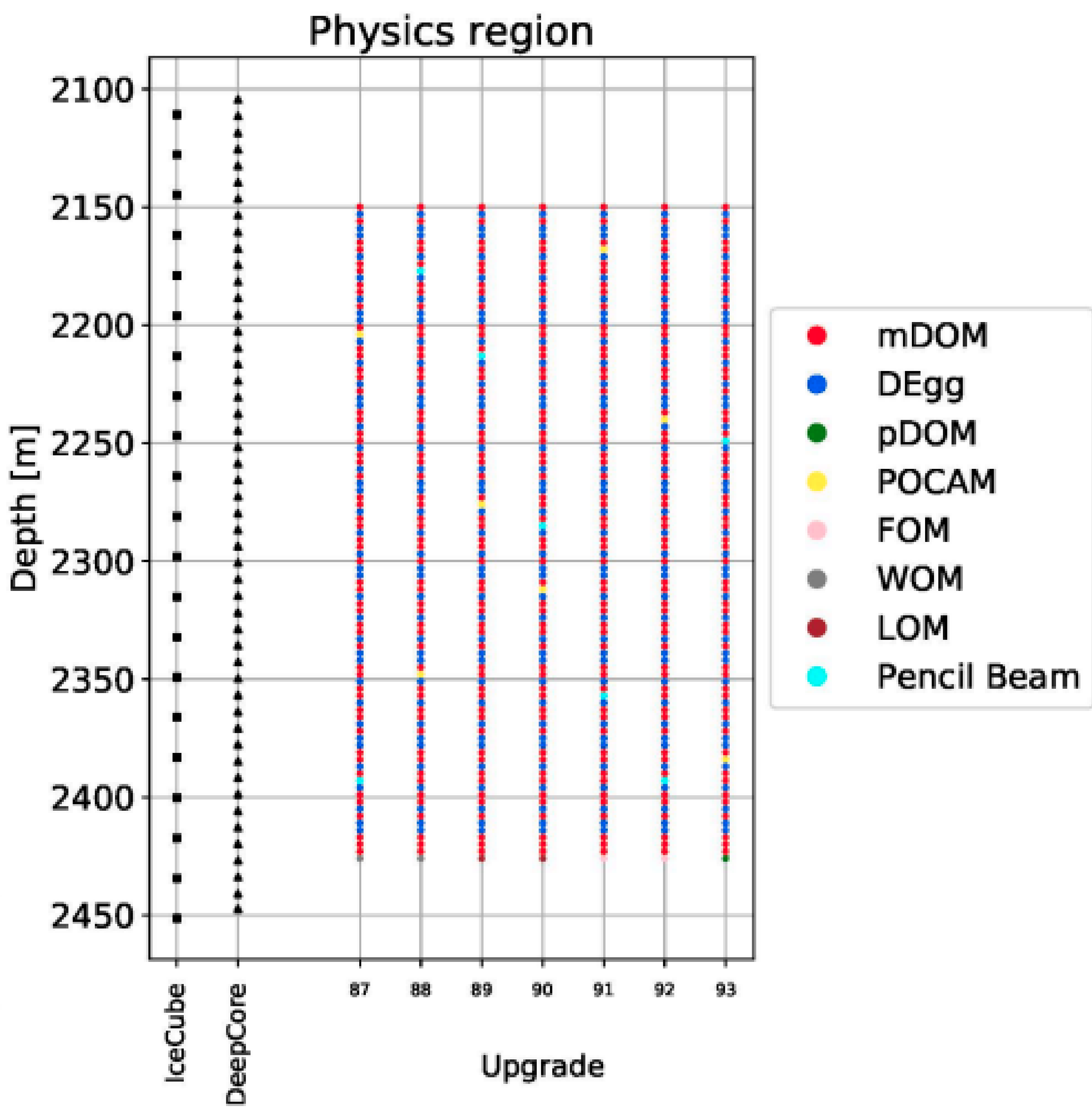


AMoRE-I

The IceCube Upgrade





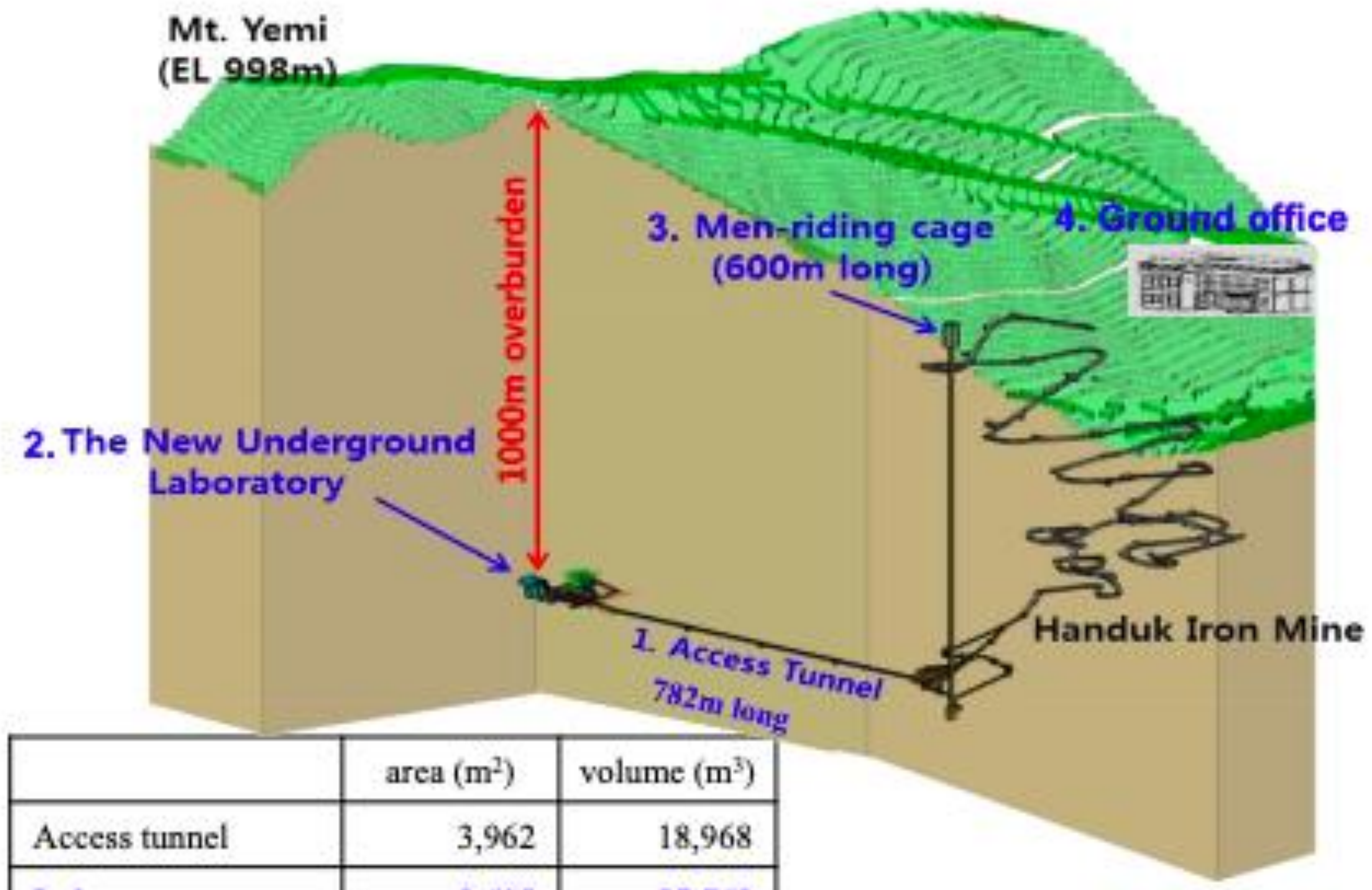


Seven New Strings to be installed in 2023/24 season.
Neutrino Oscillations and DM physics with Low energy threshold ~ few GeV.
The first stage for the next-generation neutrino telescope.

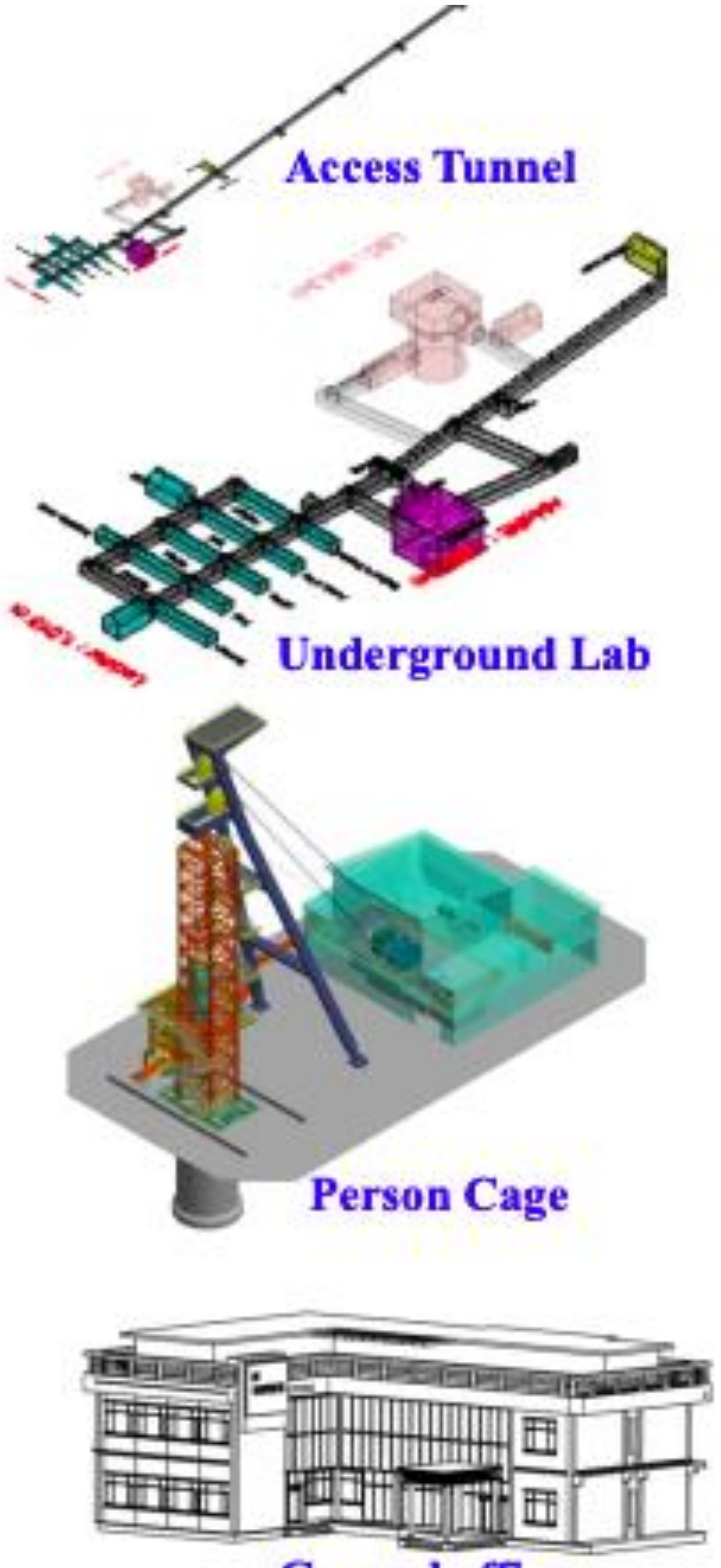
IceCube Collaboration (Full Member)

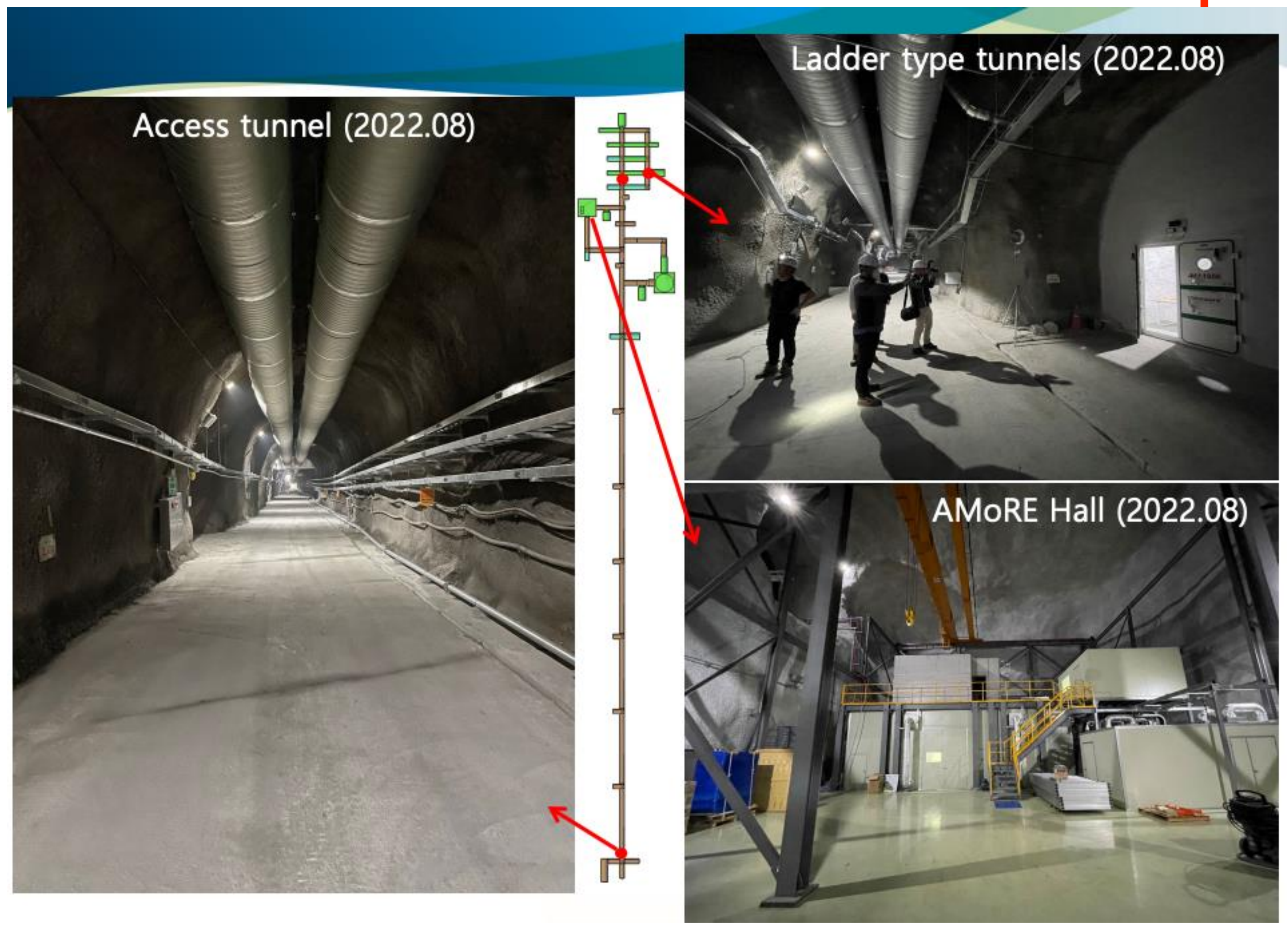
Yemilab

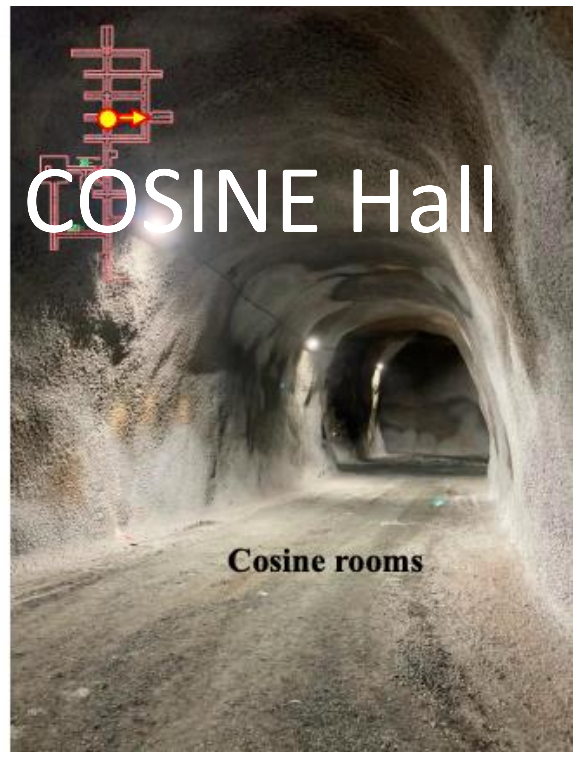
1. **Access Tunnel**, 782 m long with 12% down slope
2. **Underground Lab.** with 2600 m²
3. **Person Cage**, running vertical 587 m
4. **Ground Office** with 2500 m²



	area (m²)	volume (m³)
Access tunnel	3,962	18,968
Lab space	**2,600**	**25,562**
Connecting tunnel	4,847	14,161
amount	**11,525**	**58,691**



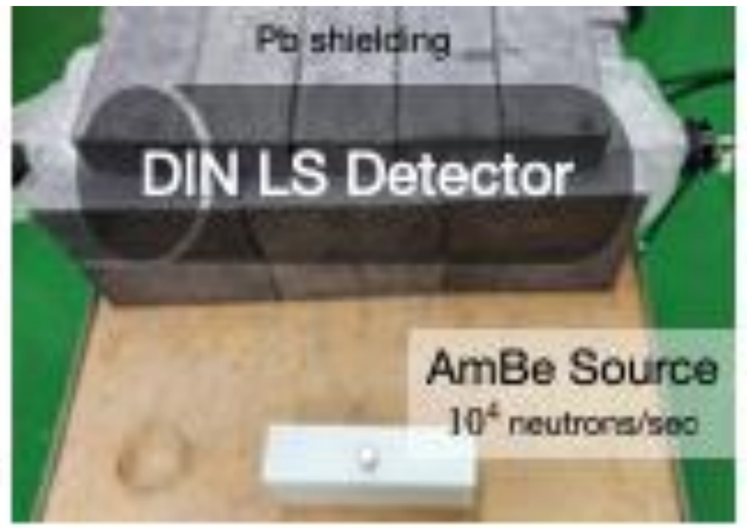




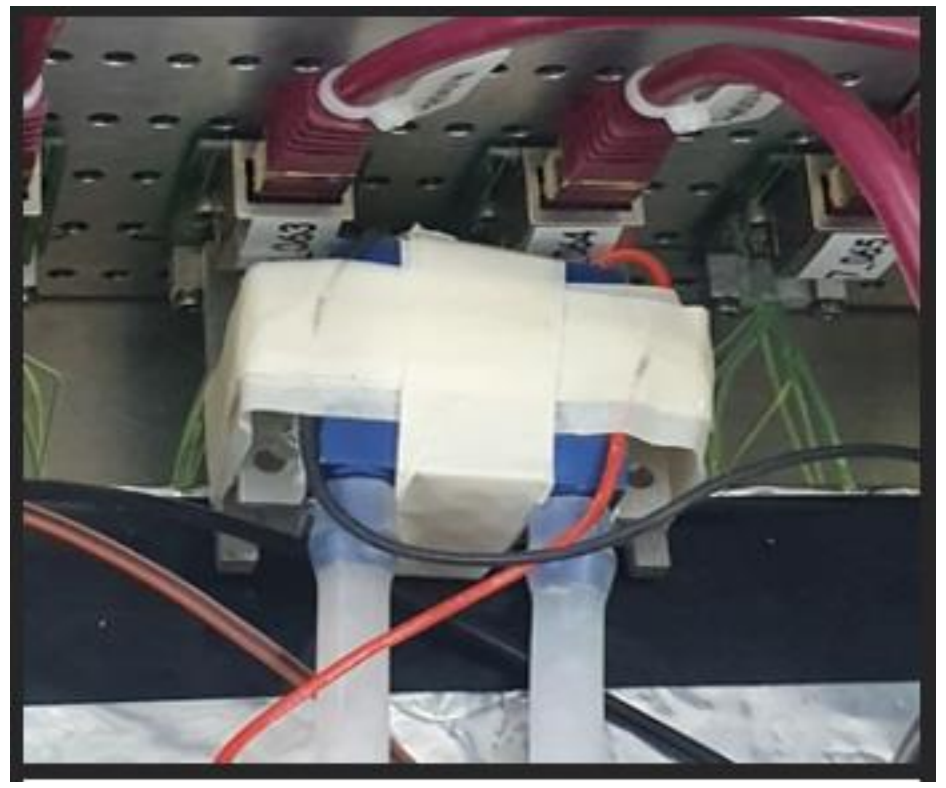
Other international activities

R&D Activities

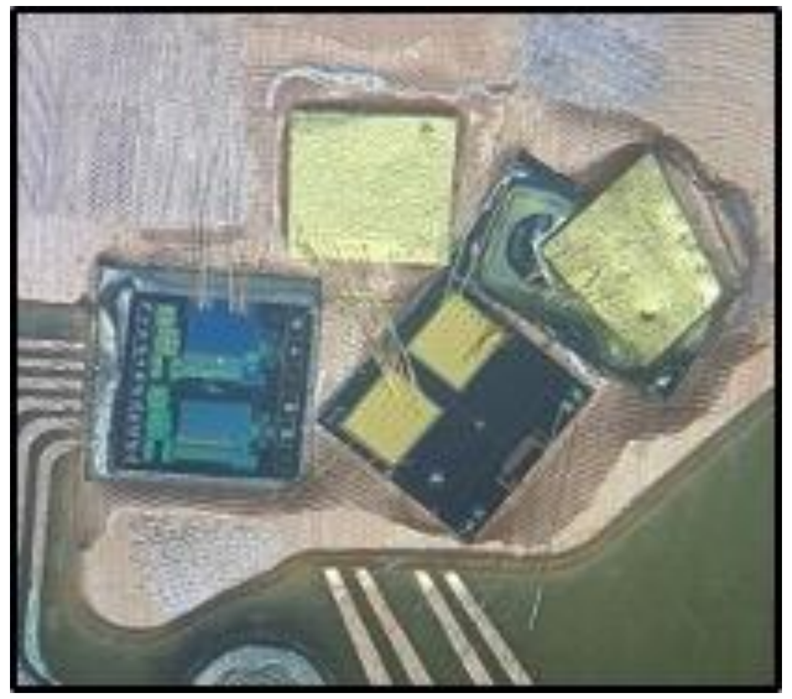
Neutron Measurement at KRISS

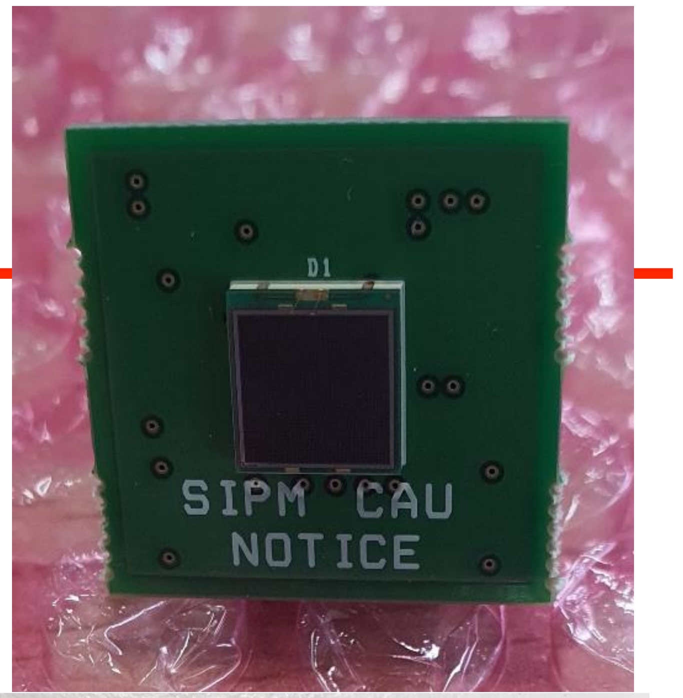


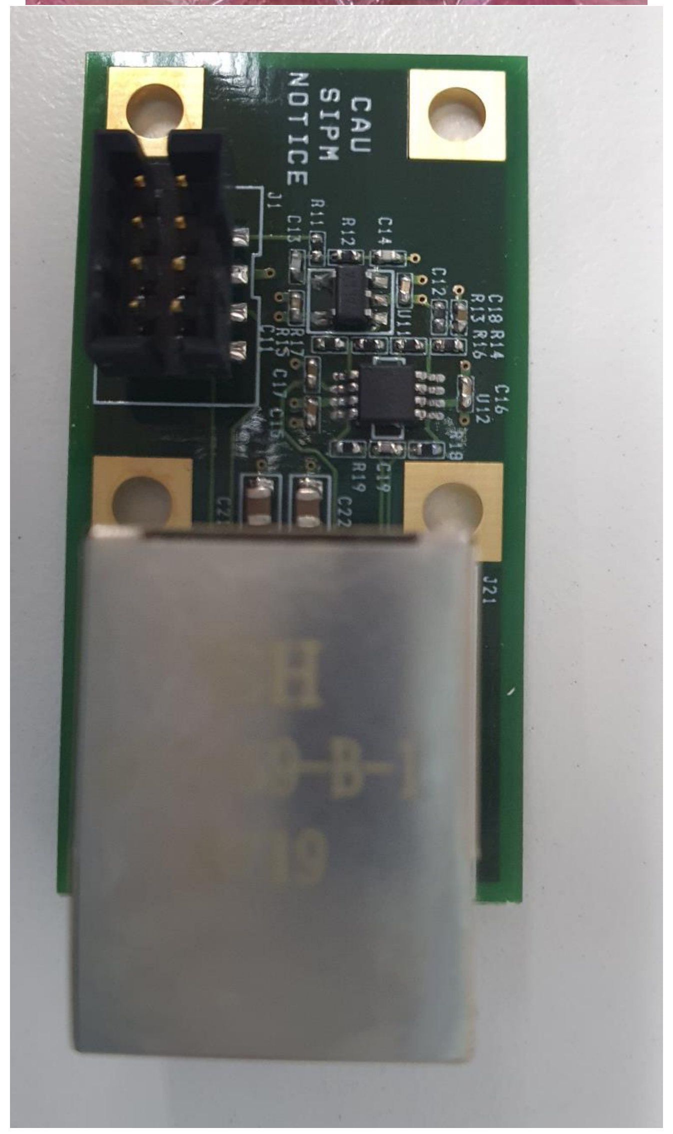
Peltier Effect



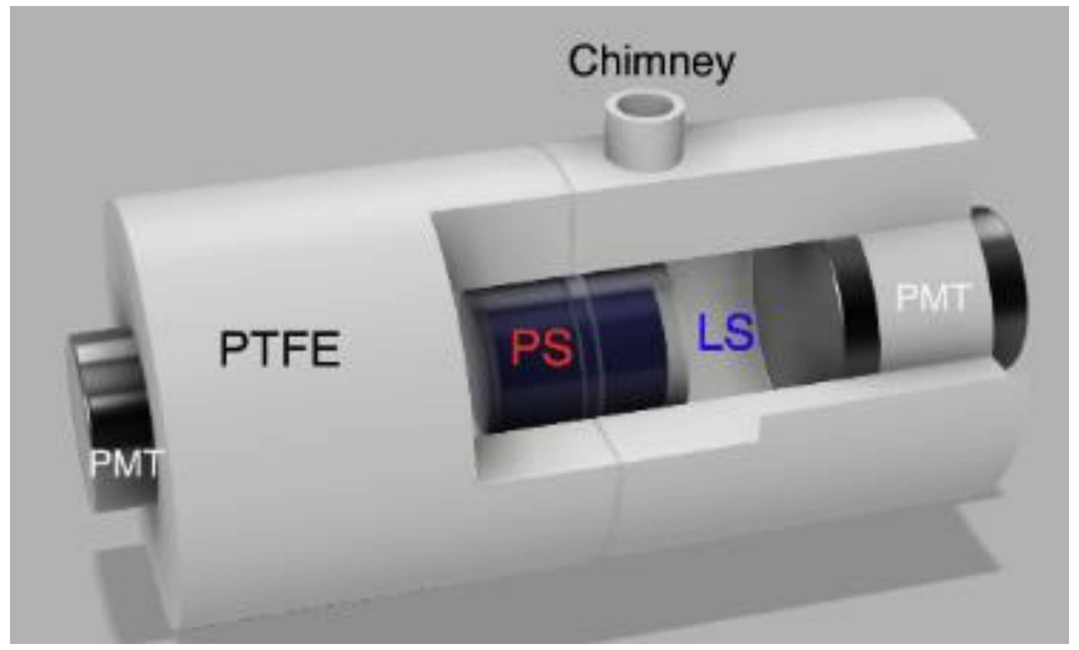
Cryogenic Detectors



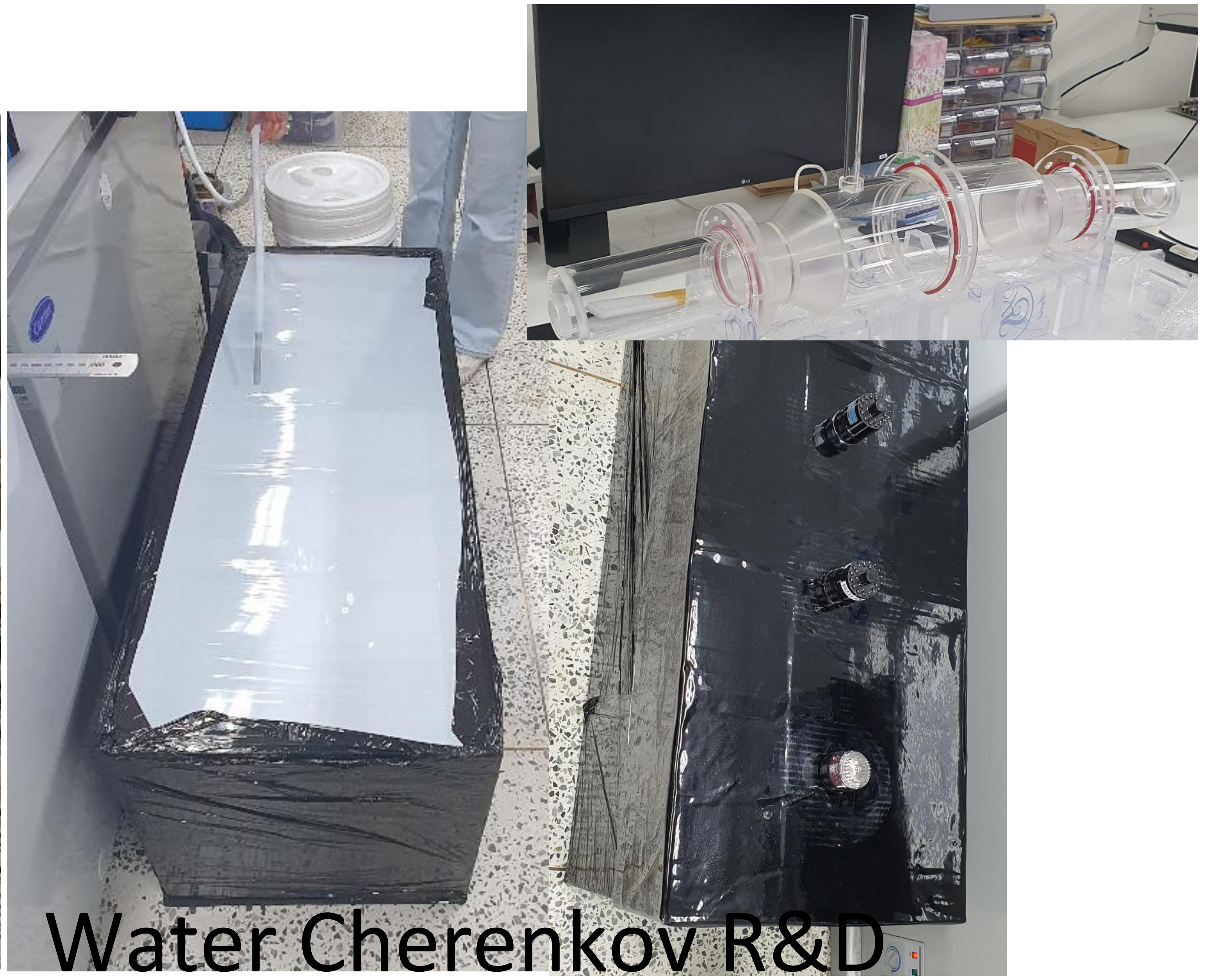




Phoswich Detector R&D



High Purity Germanium Detectors



Water Cherenkov R&D

SiPM-Liquid/Plastic Scintillator R&D

Presentations and Posters

- Publications (12 = 6 COSINE + 5 DUNE + 1 NEON), Under review (1 CAU), Draft (1 CAU + 1 COSINE)
- TAUP 2023, KREONET 2023, IceCube CM, Seminars (3)
- Korean Physical Society Meeting : Spring (2 orals + 2 posters), Fall (1 oral +2 posters)
- CAU BK21+ Workshop (2), Collaboration meetings (4)
- Schools (2), Journal Clubs (2)
- CAU-BSM, PPC2023, K-ν, NuFact2023, KPS-DPF, KPS-Spring, KPS-Fall
- Awards (1)

Milestones

- Jinyoung became Masters in Jan. 2023 and Yujin will become Masters next Month.
- COSINE & NEON pass 0.5 keV threshold barrier with Machines (BDT, NBC, and so on)
- SiPM cable extension verified.
- IceCube full membership.

COSINE-100 Experiment

Fast Neutron Analysis

Jinyoung Kim

HEP Center 2023 Winter Workshop
2023.12.27 ~ 2023.12.28 | 곤지암 리조트

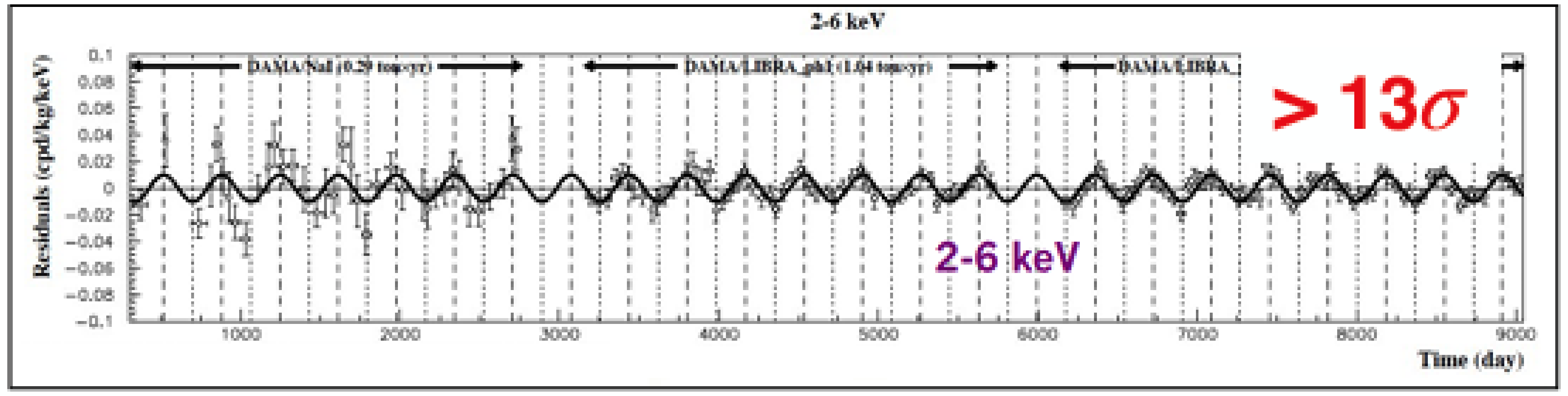
Searching for WIMPs

COSINE-100 Experiment

- ~50 collaborators in 17 institutes
- Aims to confirm/refute DAMA/LIBRA, using the same target material (NaI(Tl) Crystal)

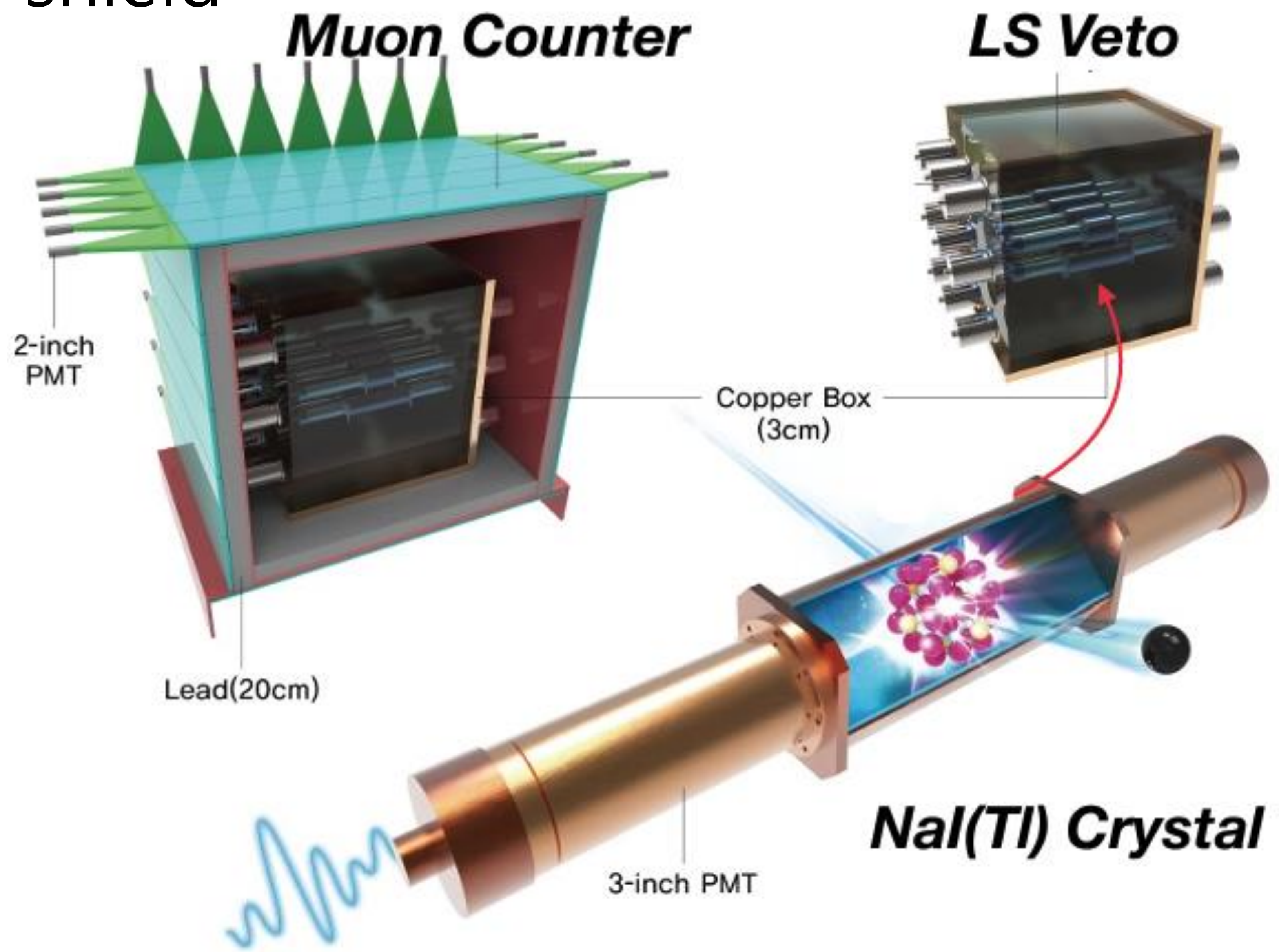
DAMA/LIBRA Modulation signal

P.Belli, EPS-HEP Conference (2021)



Detector

- 8 crystals, with a total 106kg
- Liquid & Plastic scintillator as active shield

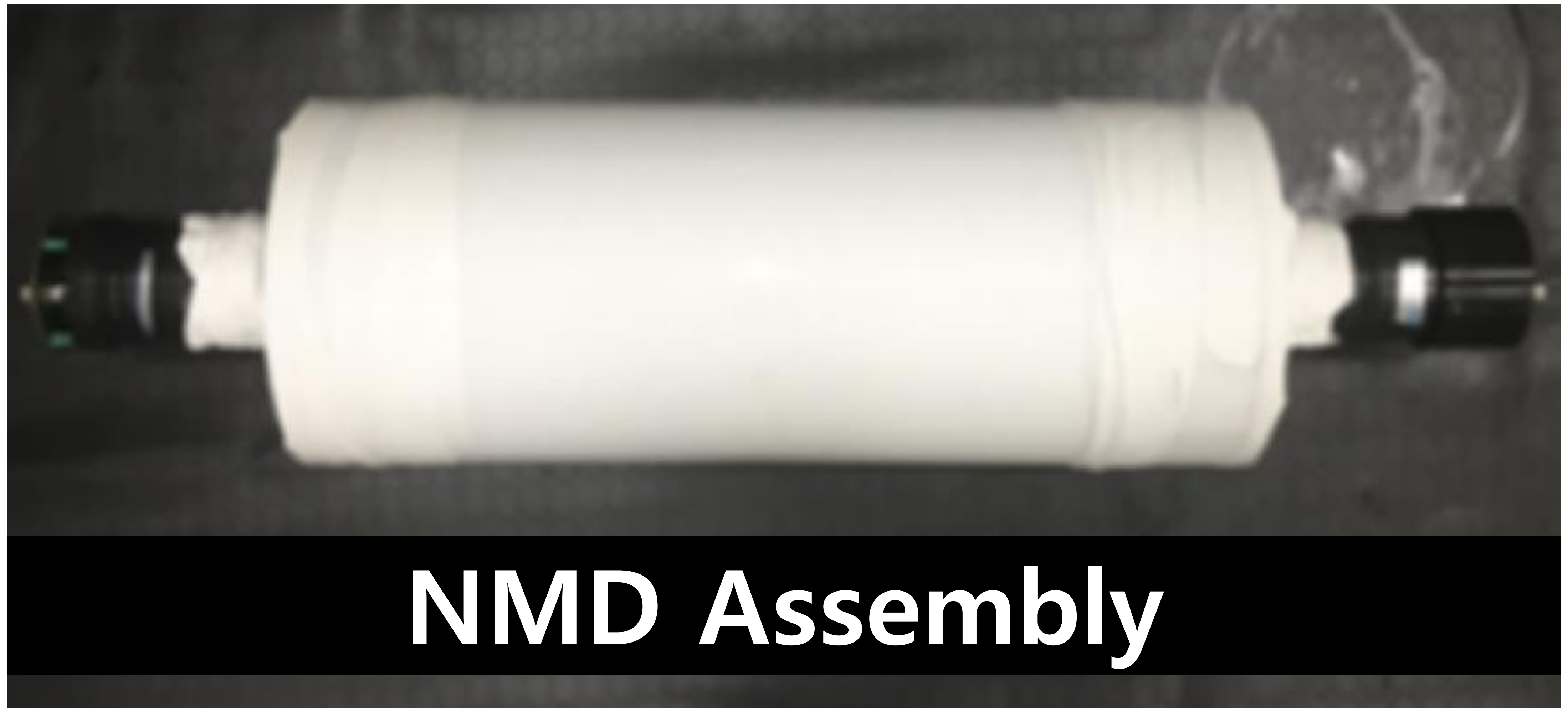


COSINE-100 Finished!

- Stable runs from *Sep 30th, 2016* to *Mar. 14th, 2023*
- Now preparing COSINE-100 Upgrade

Neutron Monitoring Detector

- Because neutron events can mimic WIMPs signal, it is important to check environment neutron behavior.
- Monitoring environmental neutrons as well as muon induced neutrons is necessary
- NMD to monitor the environmental neutrons are installed outside the shielding
- We have ~4 year data (Oct 2018 ~ Mar 2023)



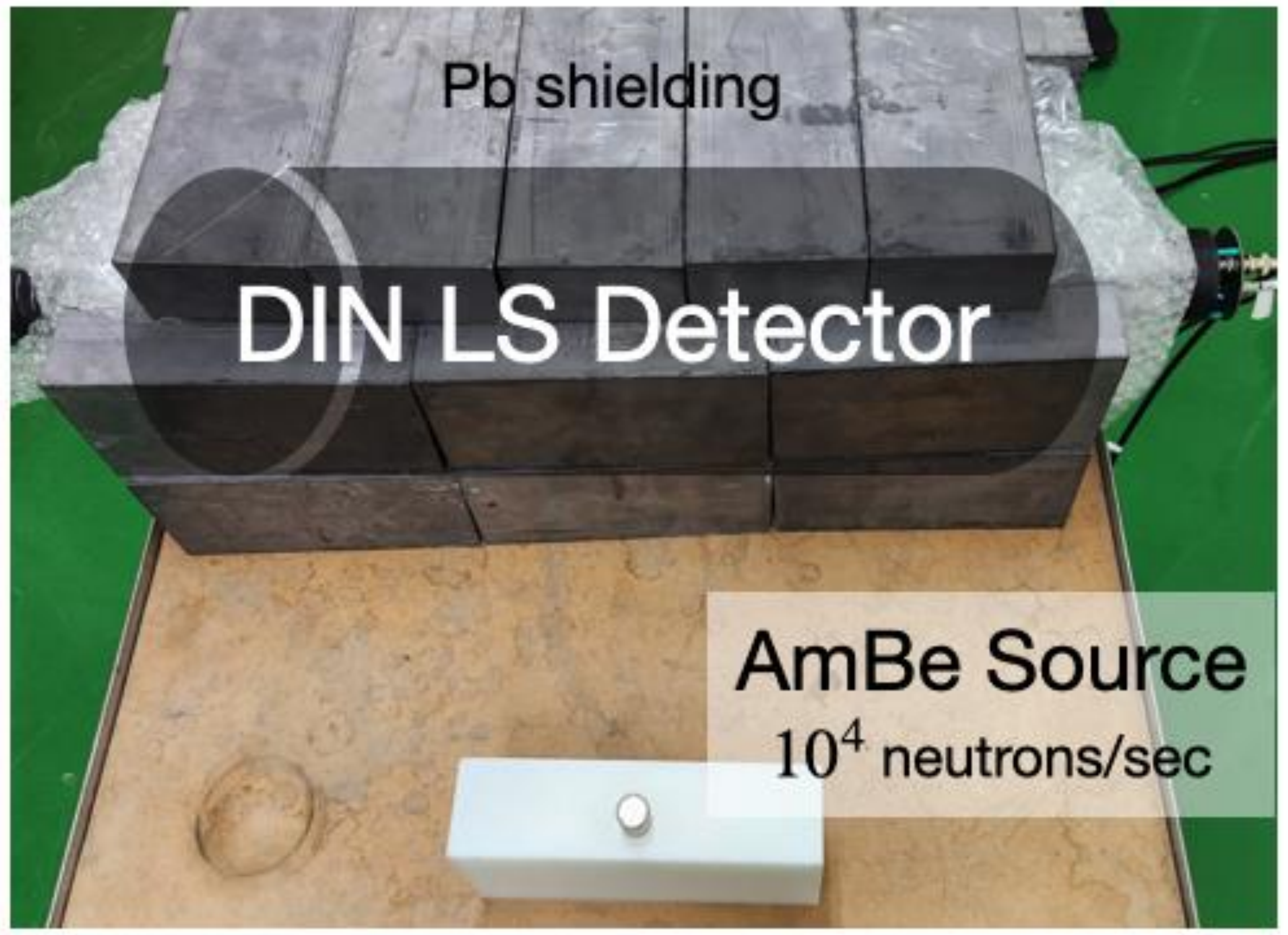
Fast Neutron Detector

- Ultima GoldF (5.52kg)
- Teflon(400mm x ø 130mm) having 15mm thickness
- Acrylic Window
- 5′′ Hamamatsu PMTs

@KRISS

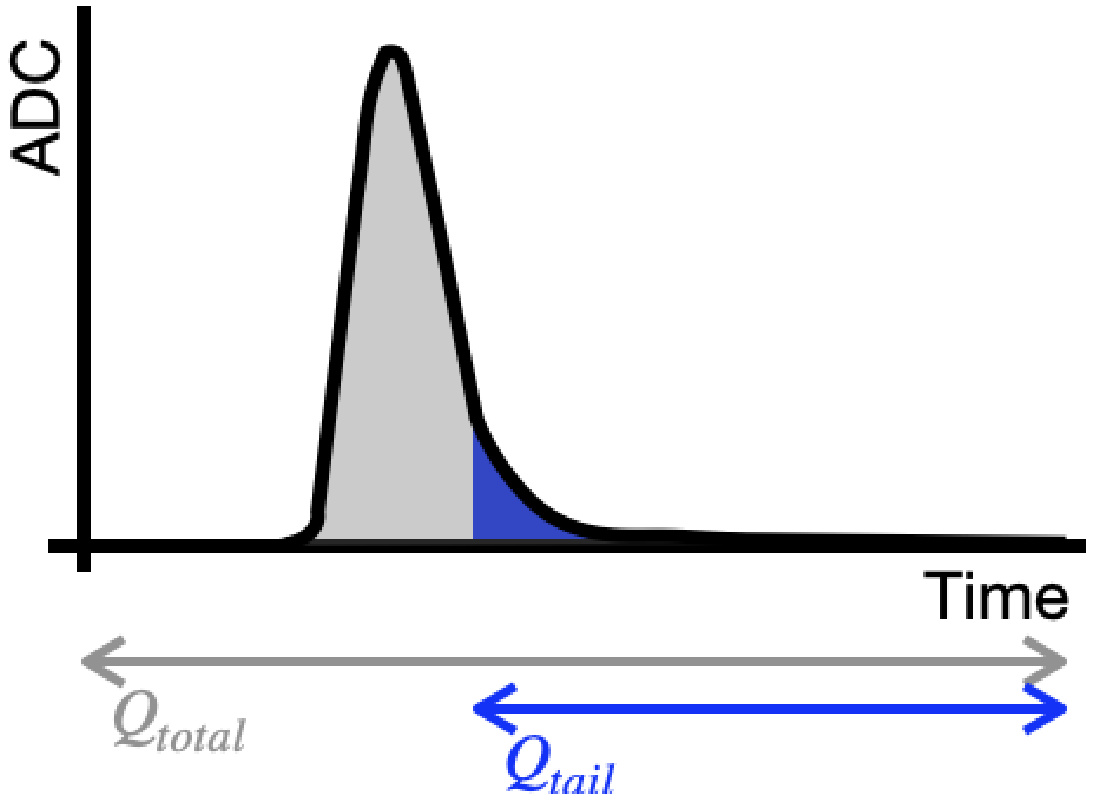
Neutron Calibration Data

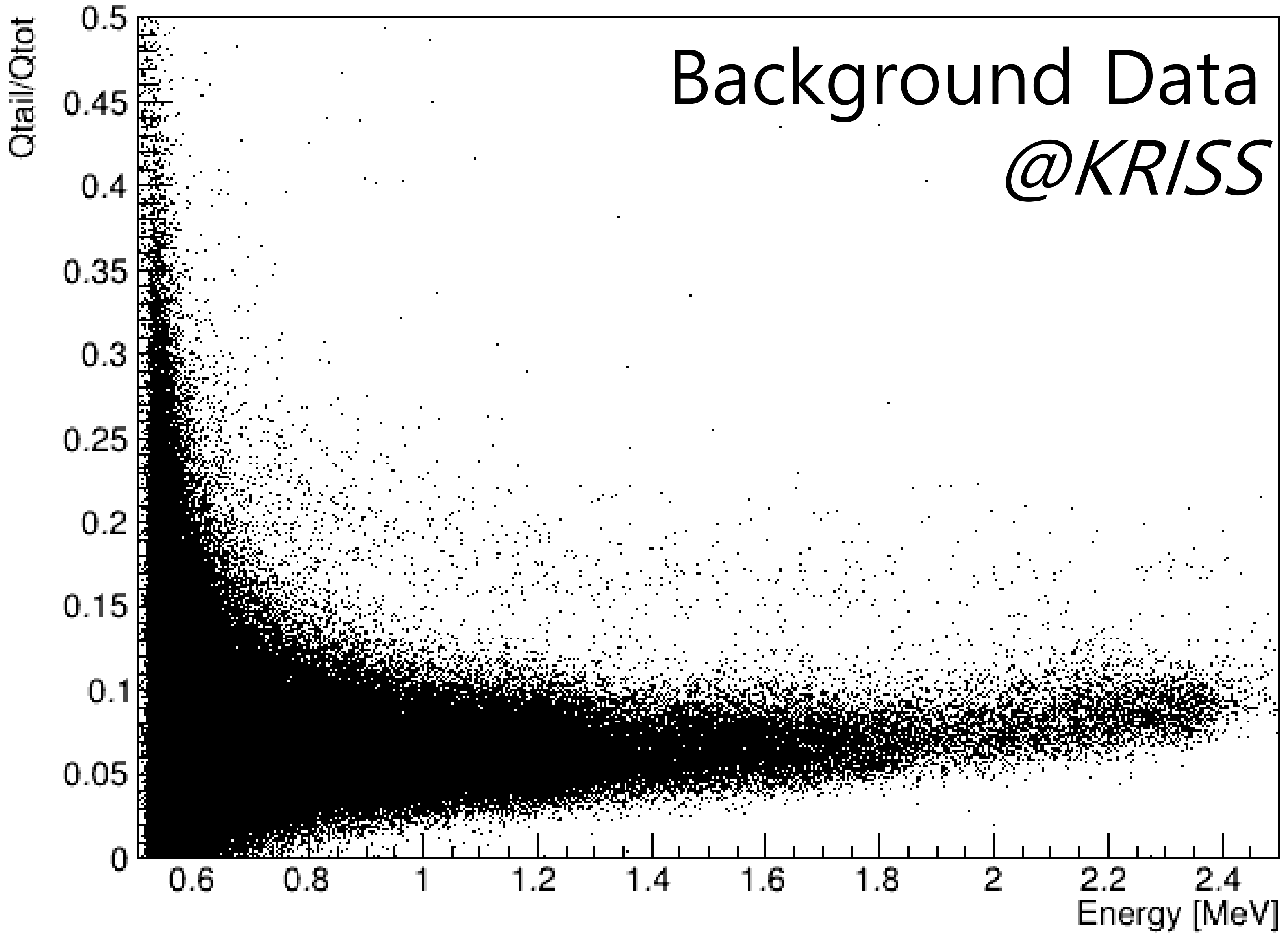
Detector Set-up

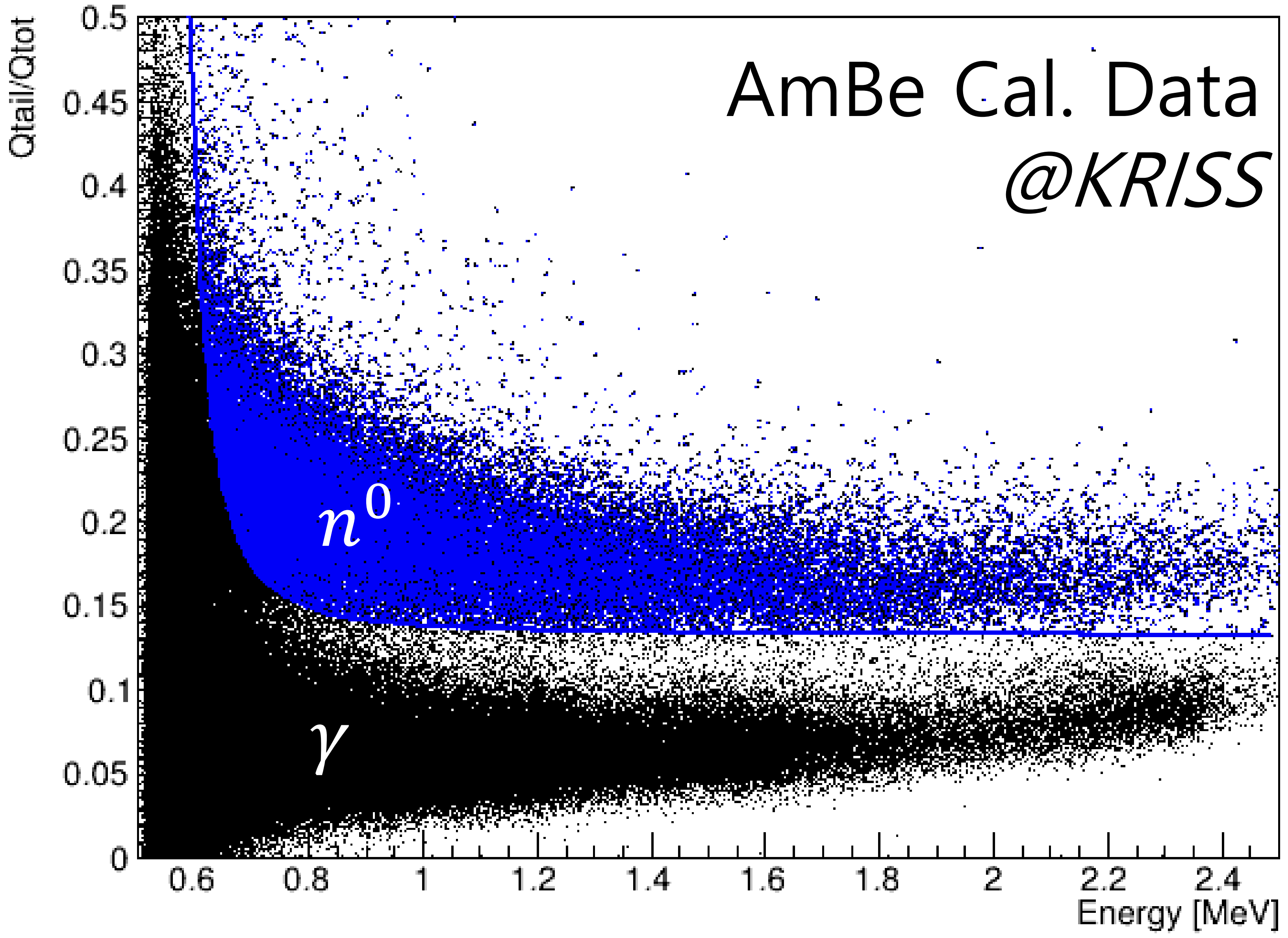


Neutron Selection

using Qtail/Qtot parameter

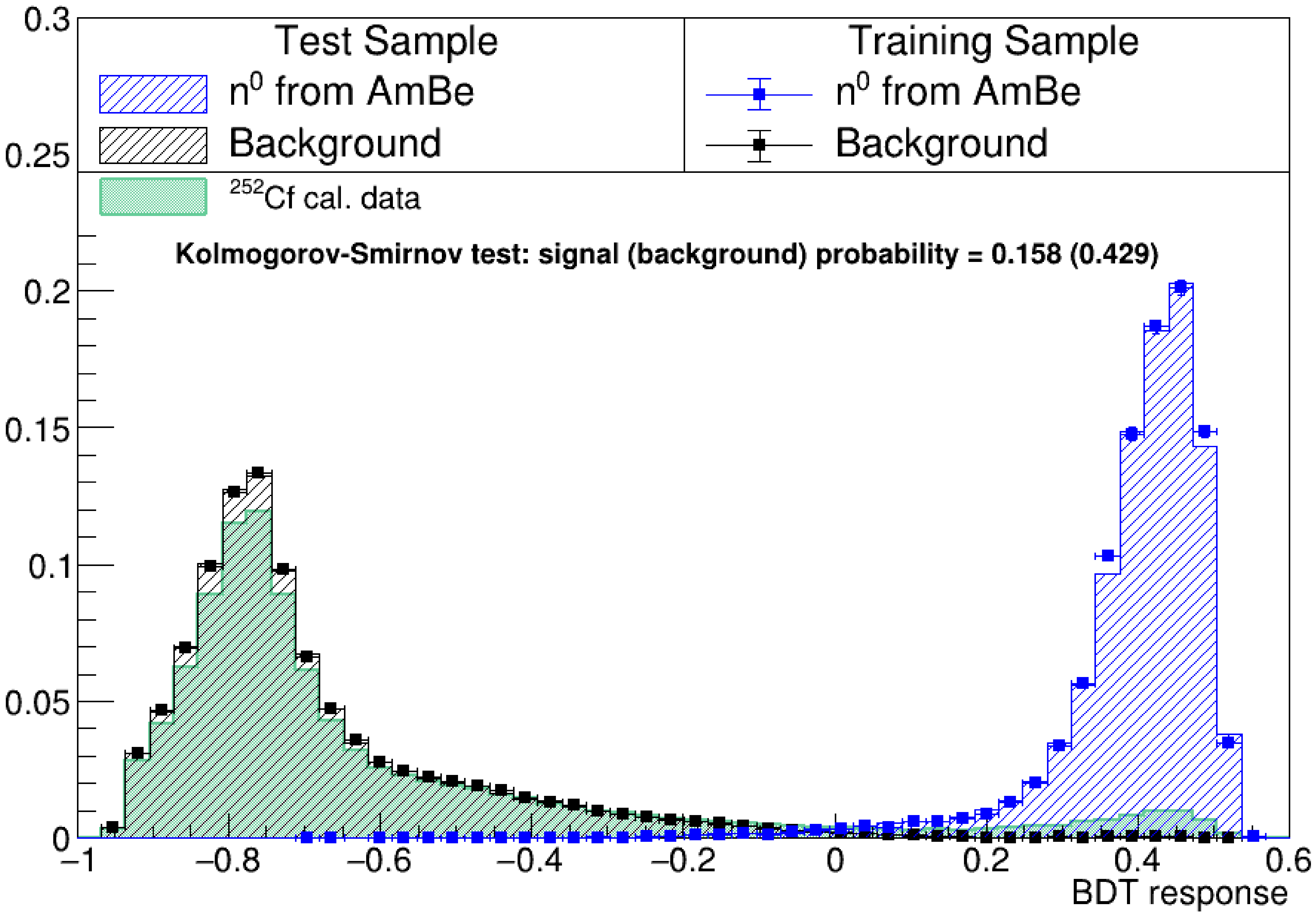


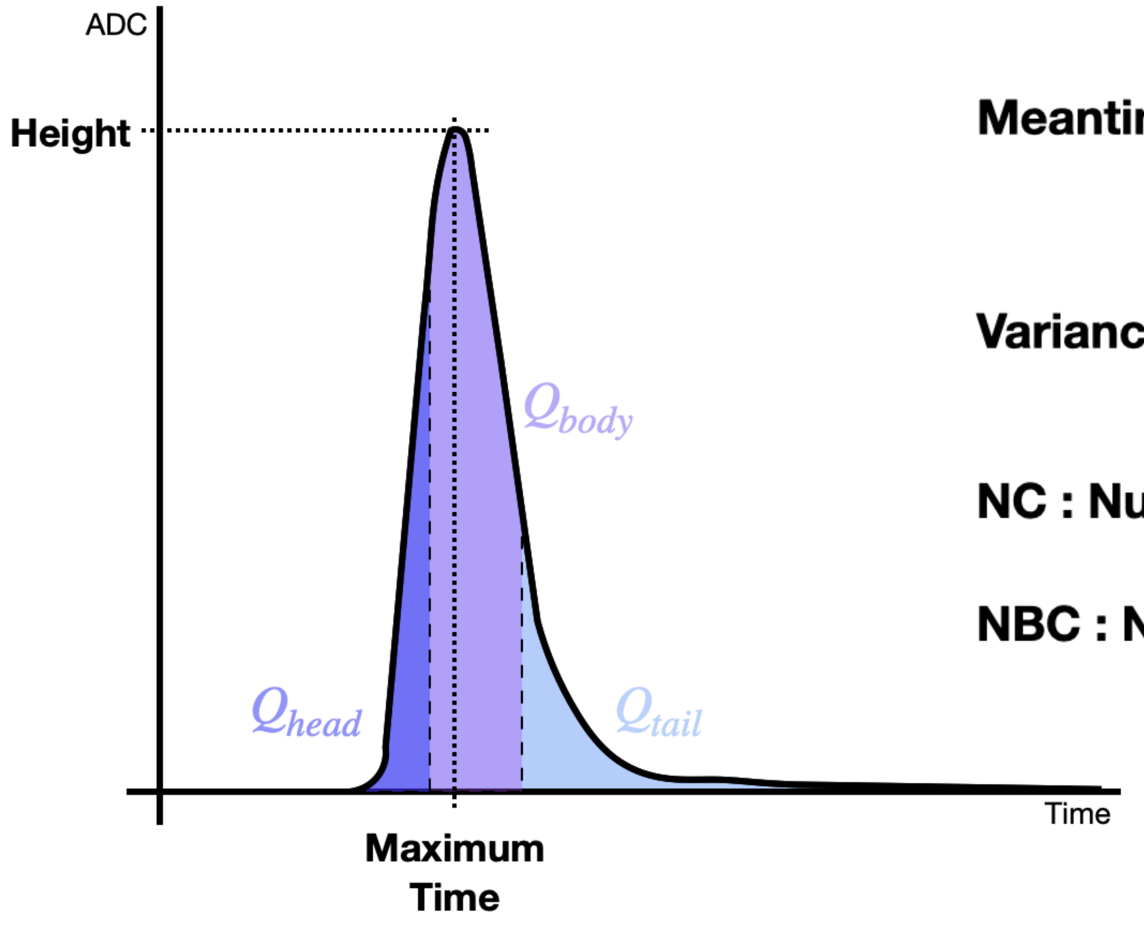




Boosted Decision Tree (BDT)

Machine Learning Using the Calibration Data



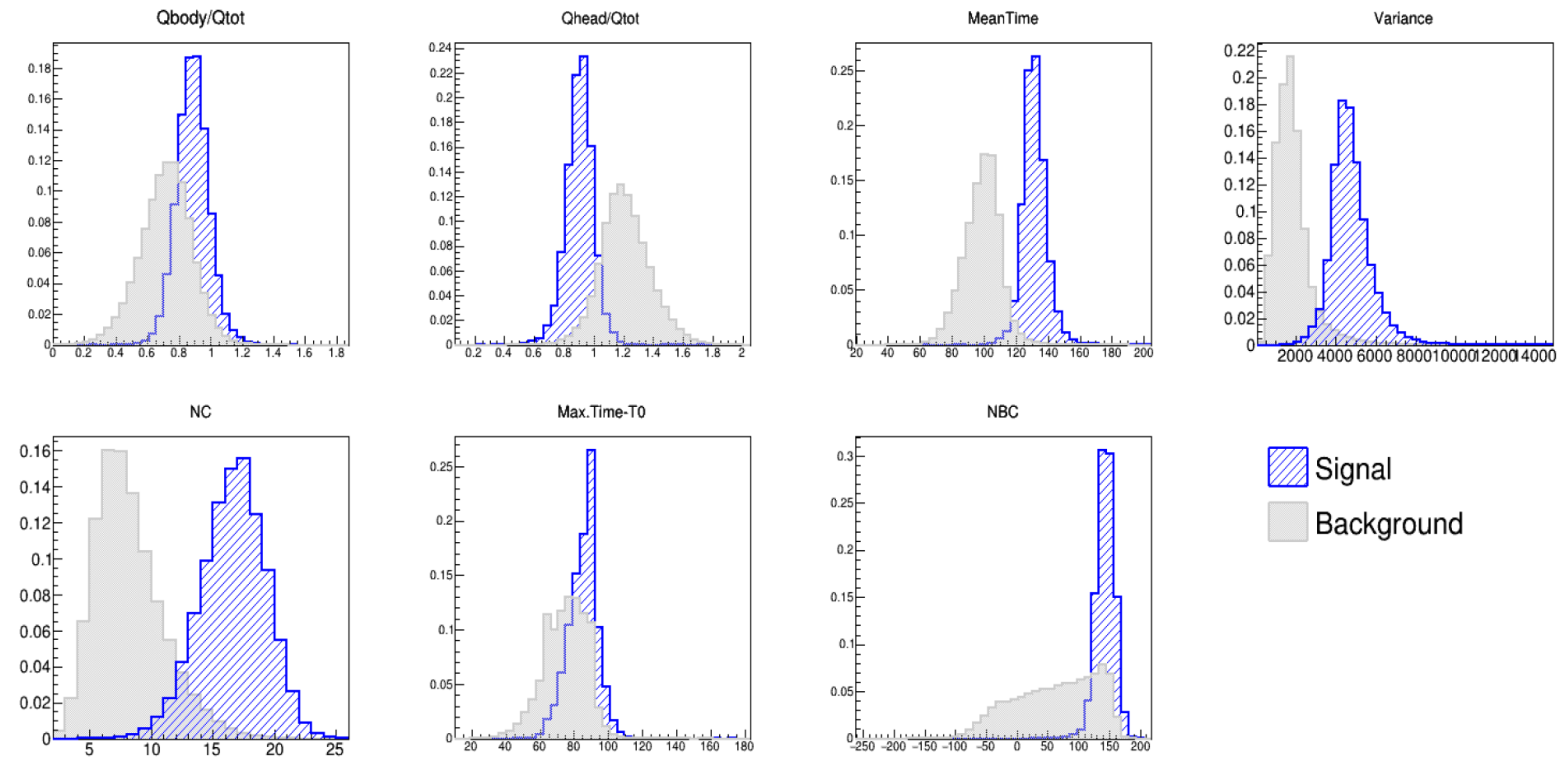


Meantime = $\frac{\Sigma q_i t_i}{\Sigma q_i}$

Variance = $\frac{\Sigma q_i t_i^2}{\Sigma q_i} - (\frac{\Sigma q_i t_i}{\Sigma q_i})^2$

NC : Number of Clusters

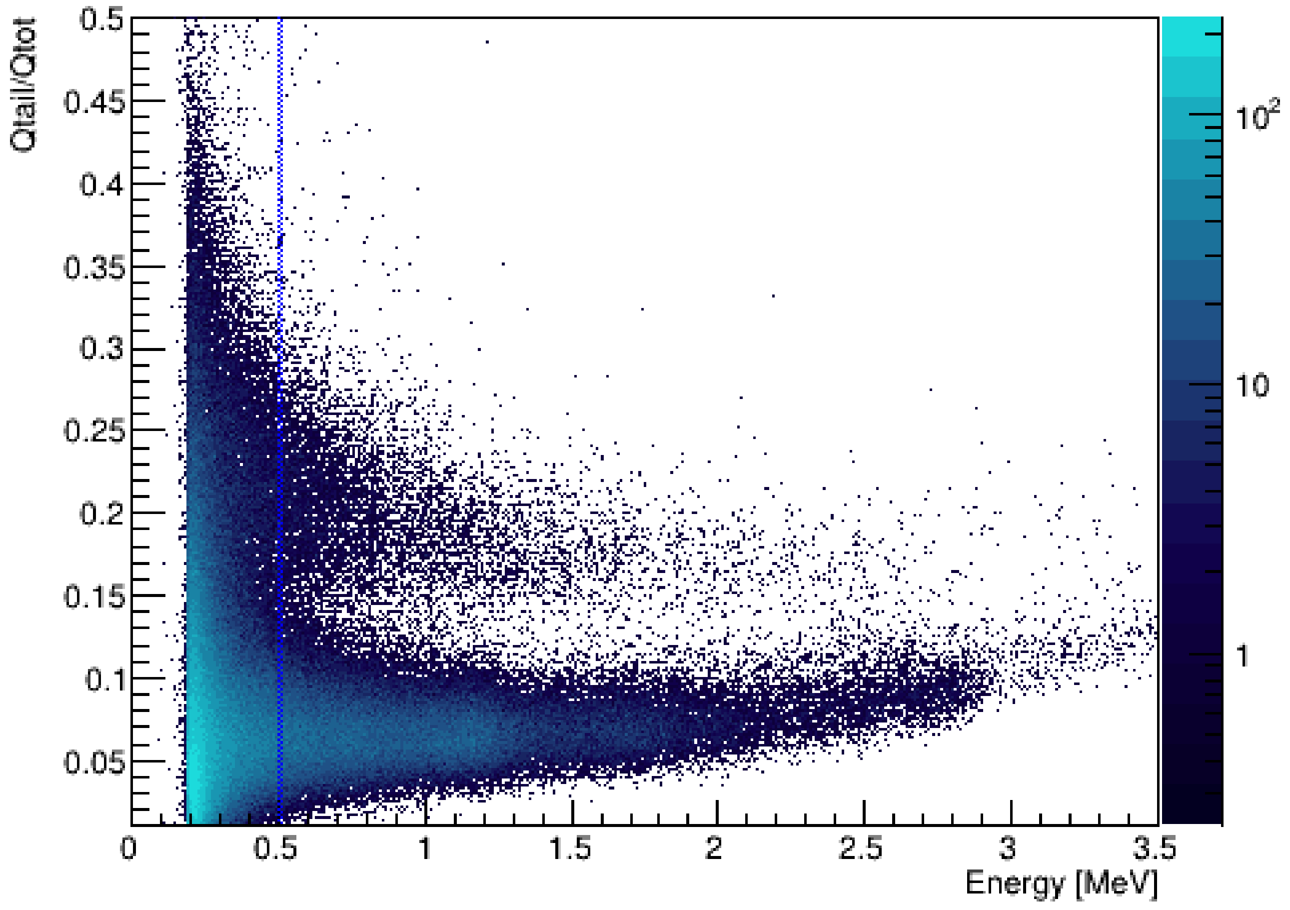
NBC : Naive Bayes Classifier

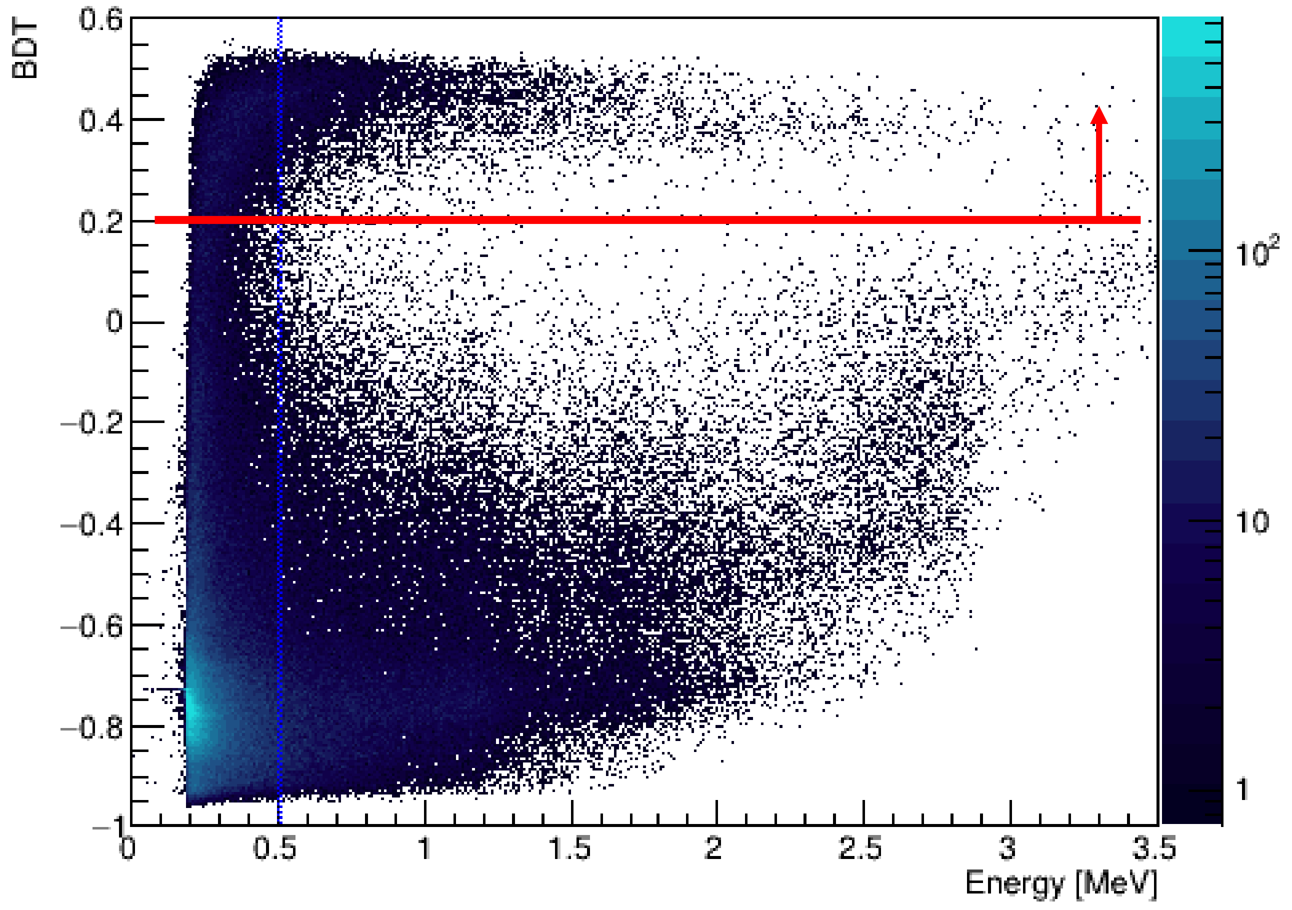


Boosted Decision Tree (BDT)

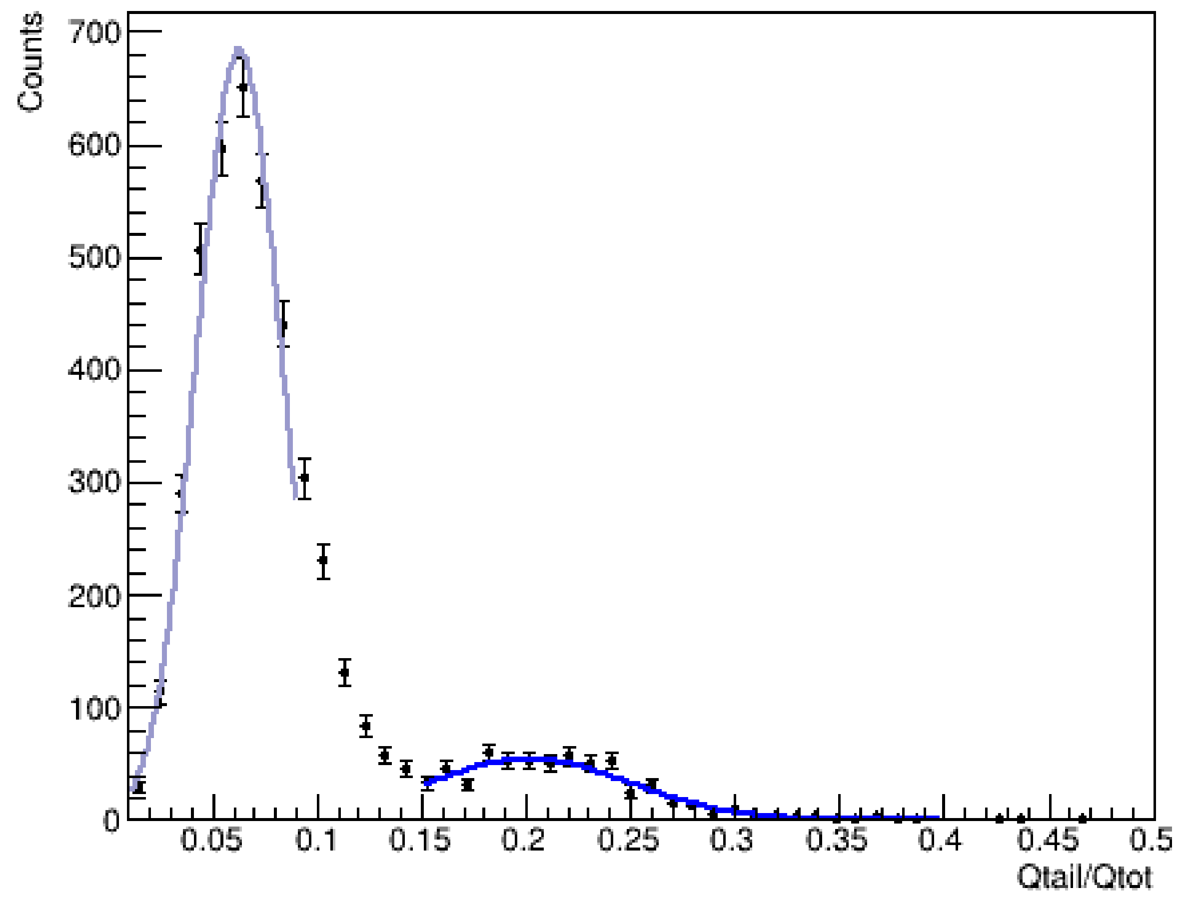
Applying the Machine on Physics Data

Cf-252 Calibration Data *@KRISS*





Decide cut "BDT > 0.2" for γ rejection



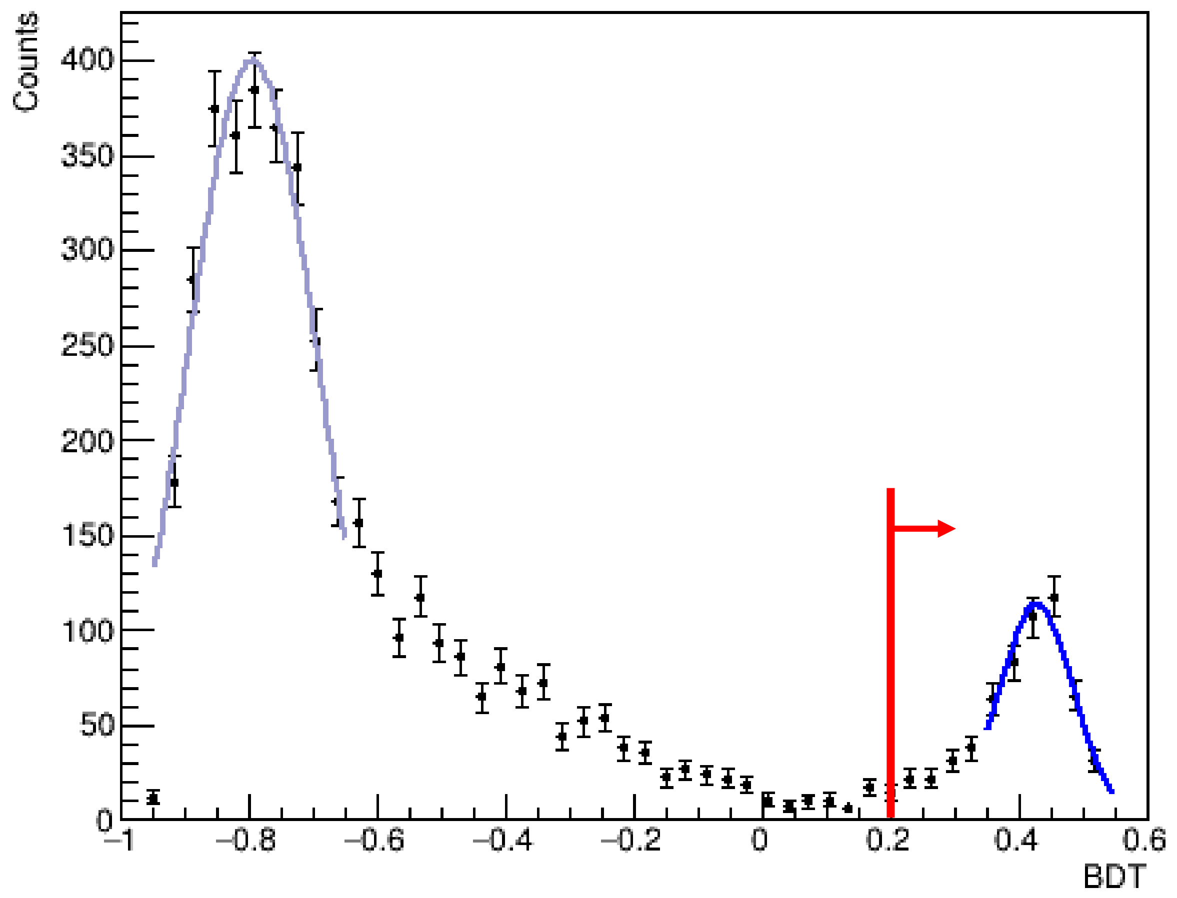
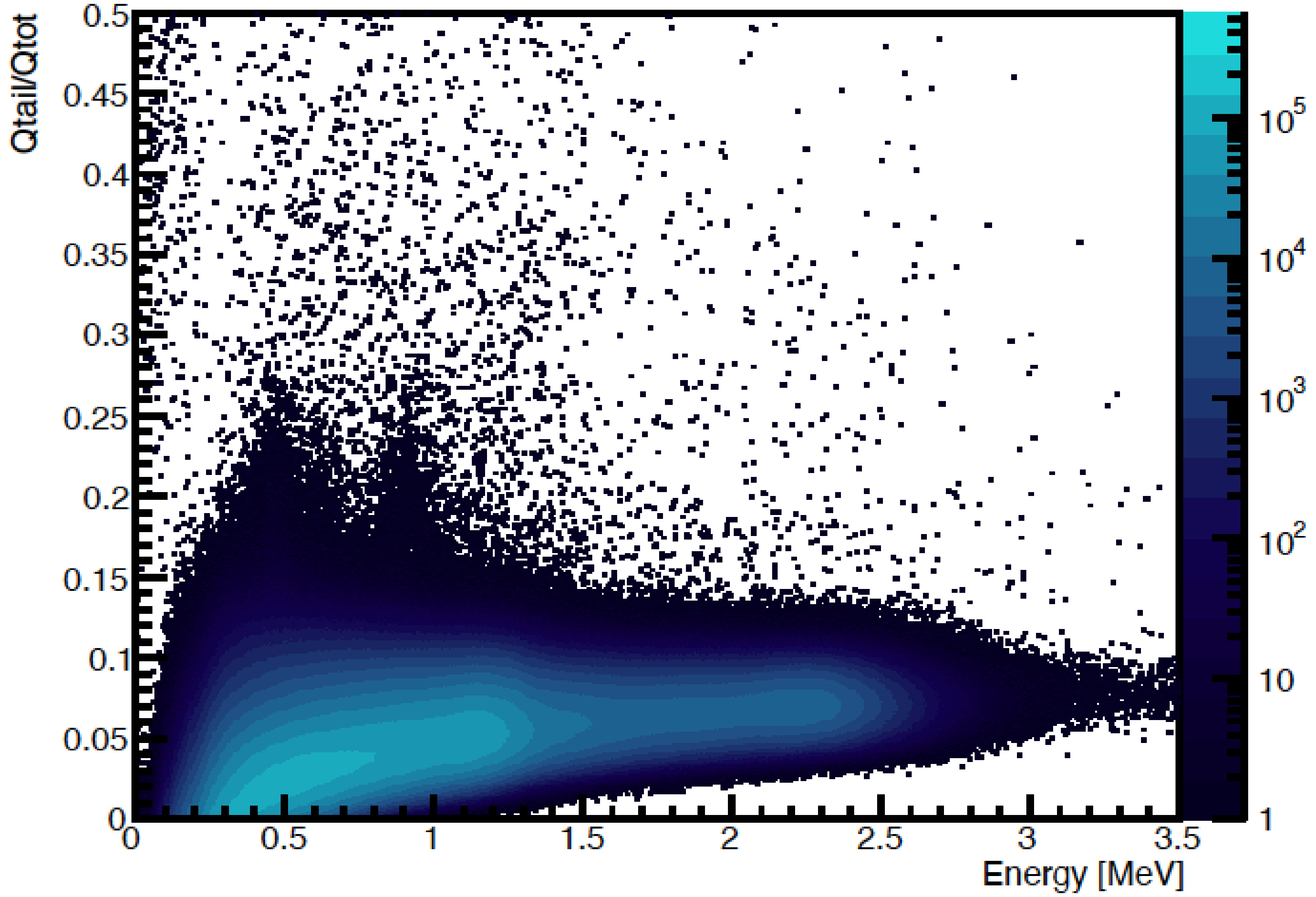


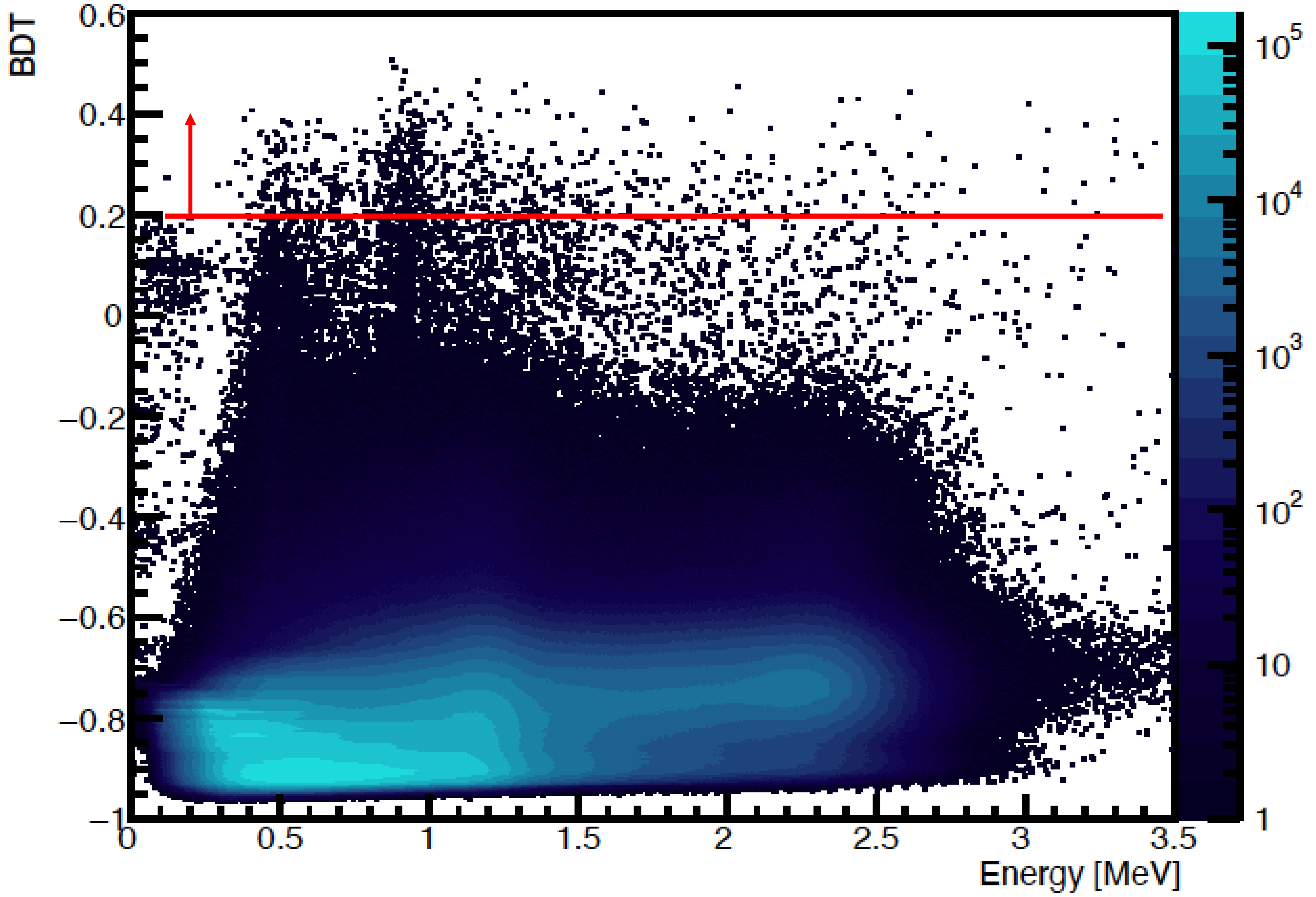
Figure of Merit (F.O.M)

$2.6\sigma \rightarrow 10.4\sigma$

Applying the Machine on Physics Data

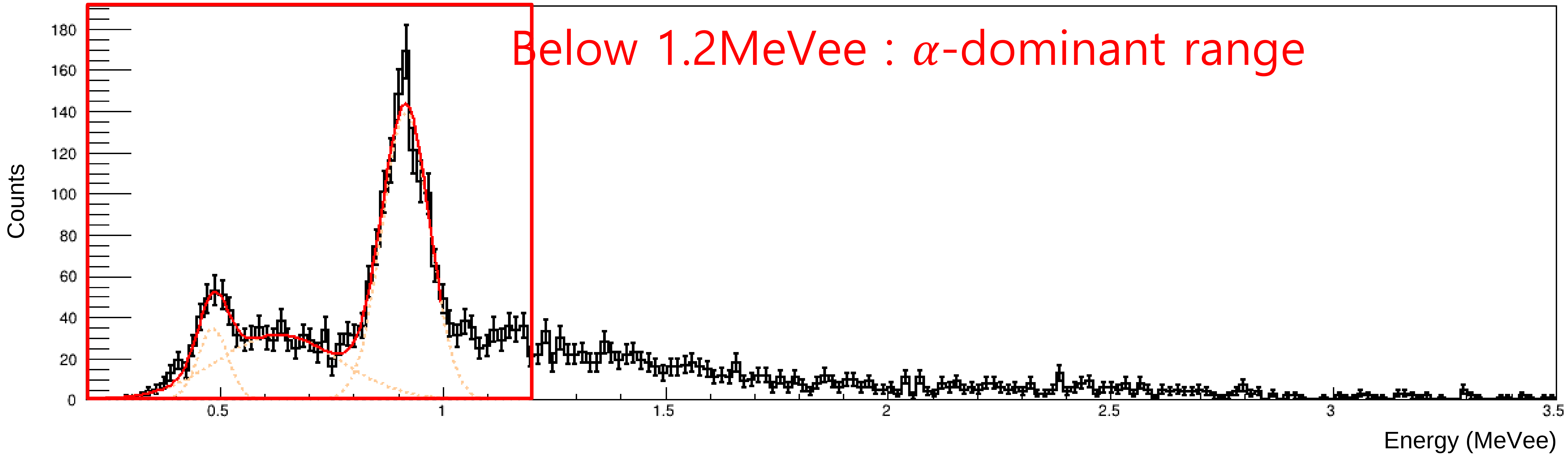
Physics Data *@Y2L*



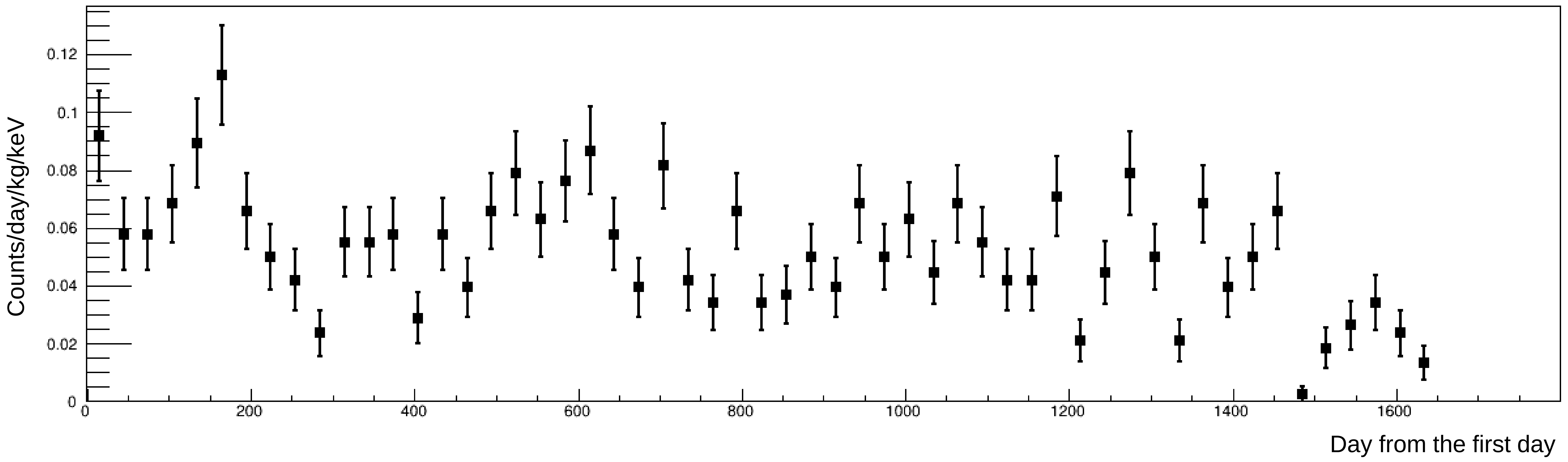


After BDT Cut

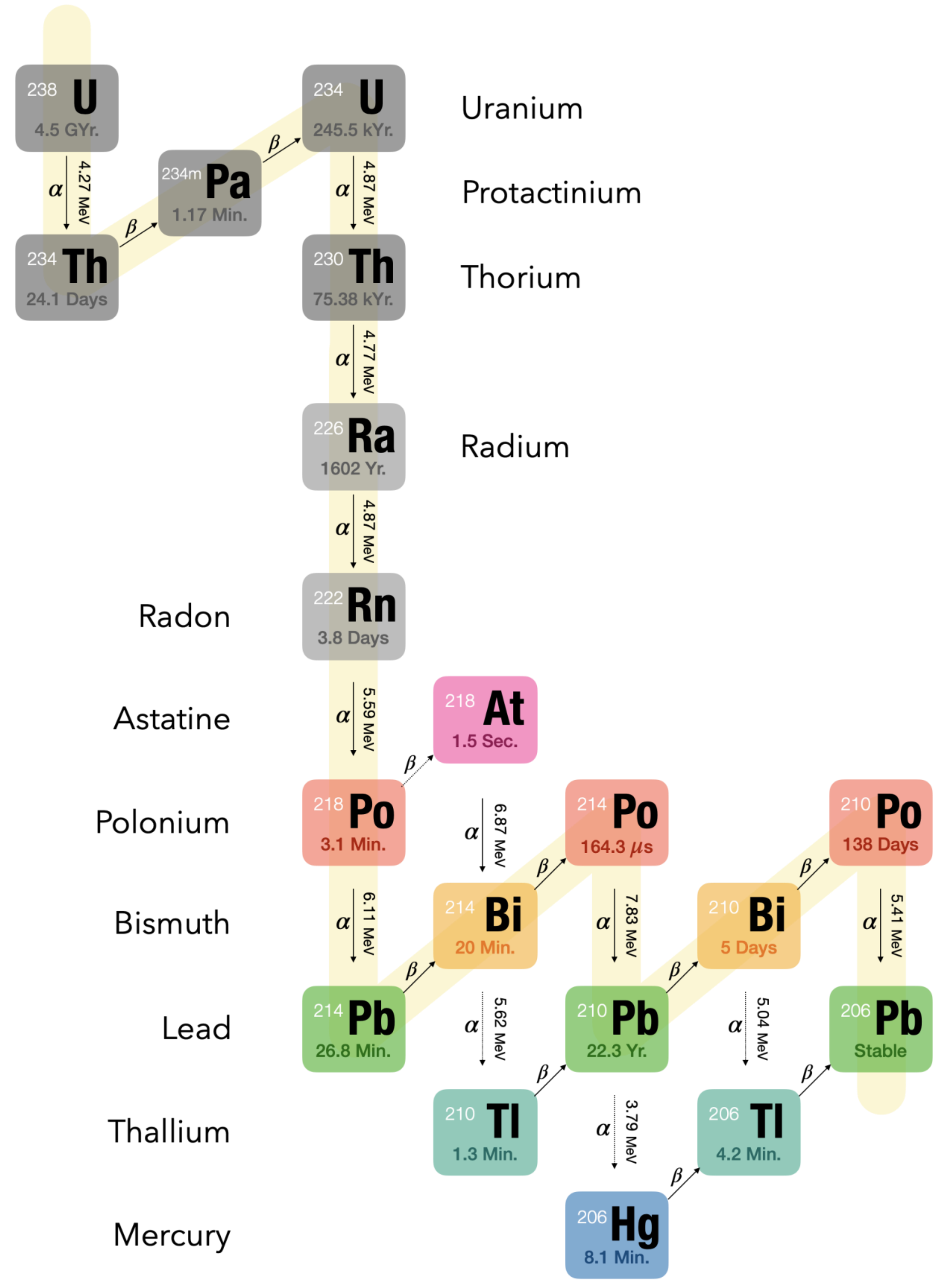
Neutron Data Energy Distribution & Event Rates



Event Rate (>1.2 MeVee)

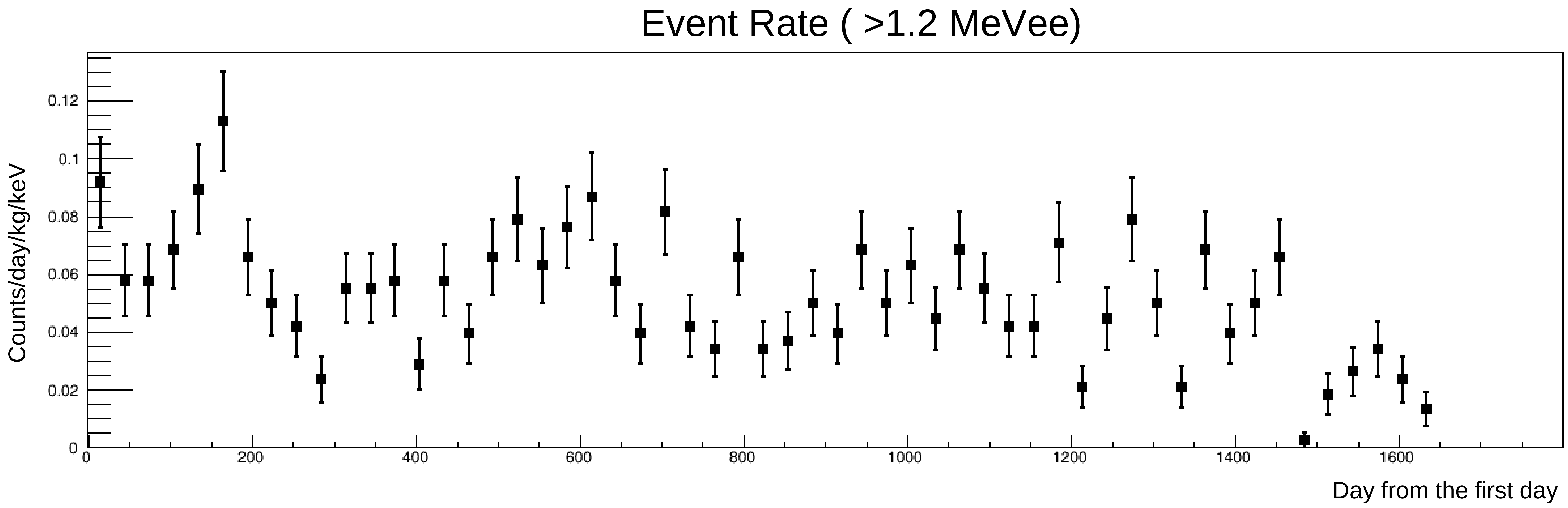


U-238 Decay Chain



Plan

- Efficiency correction on event rate histogram
- Searching for the neutron modulation in our data



Summary

- Neutron events can mimic WIMPs signal, so we have installed NMD
- Discrimination of γ from n^0 was tested by using AmBe calibration data at KRISS
- After using BDT, we can distinguish neutron data with FOM >> 5σ
- After BDT cut as γ rejection, data below 1.2 MeV was rejected because it is α-dominant range

- After efficiency correction, we're going to search for the neutron modulation in our data

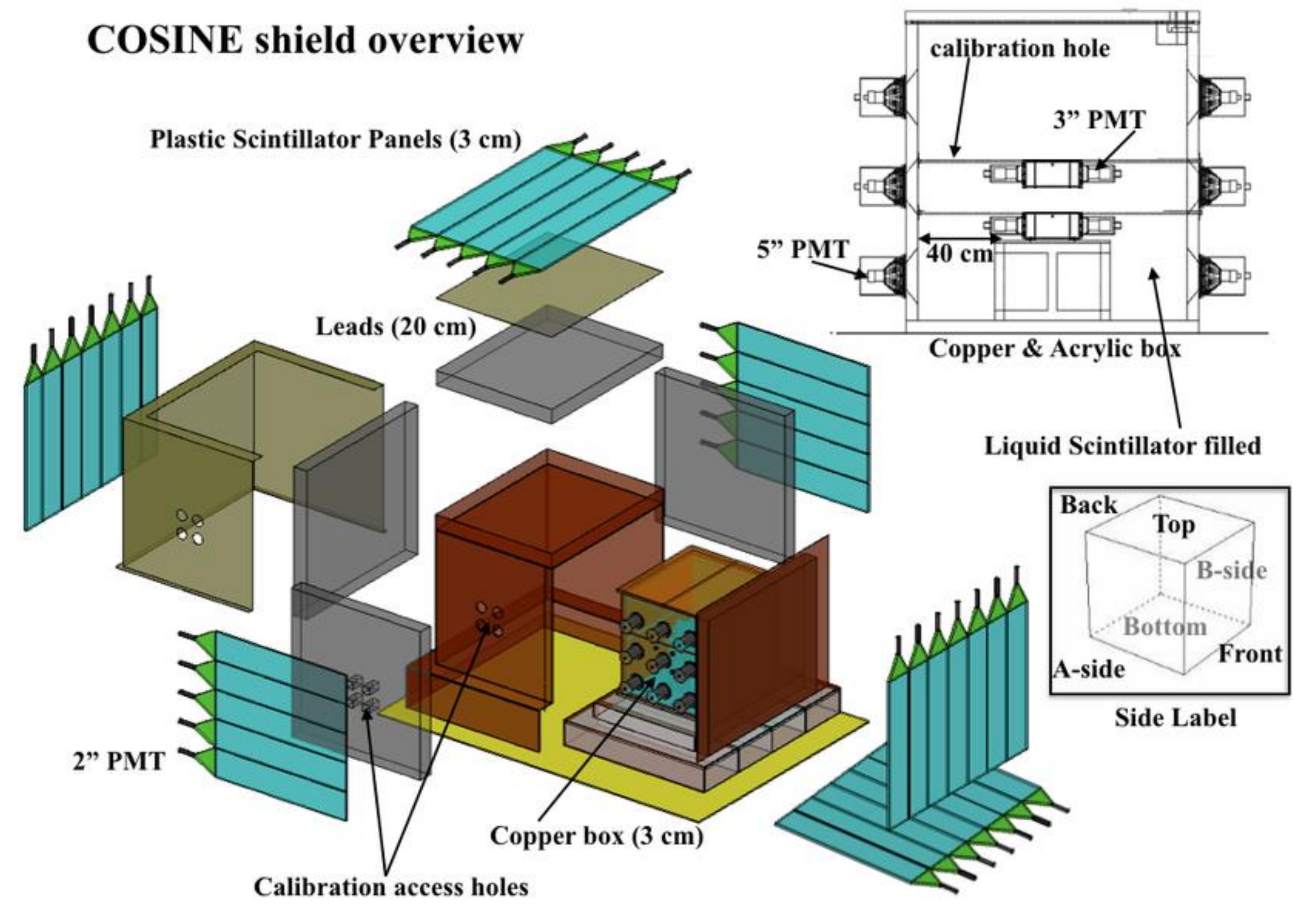
2023 Research Summary

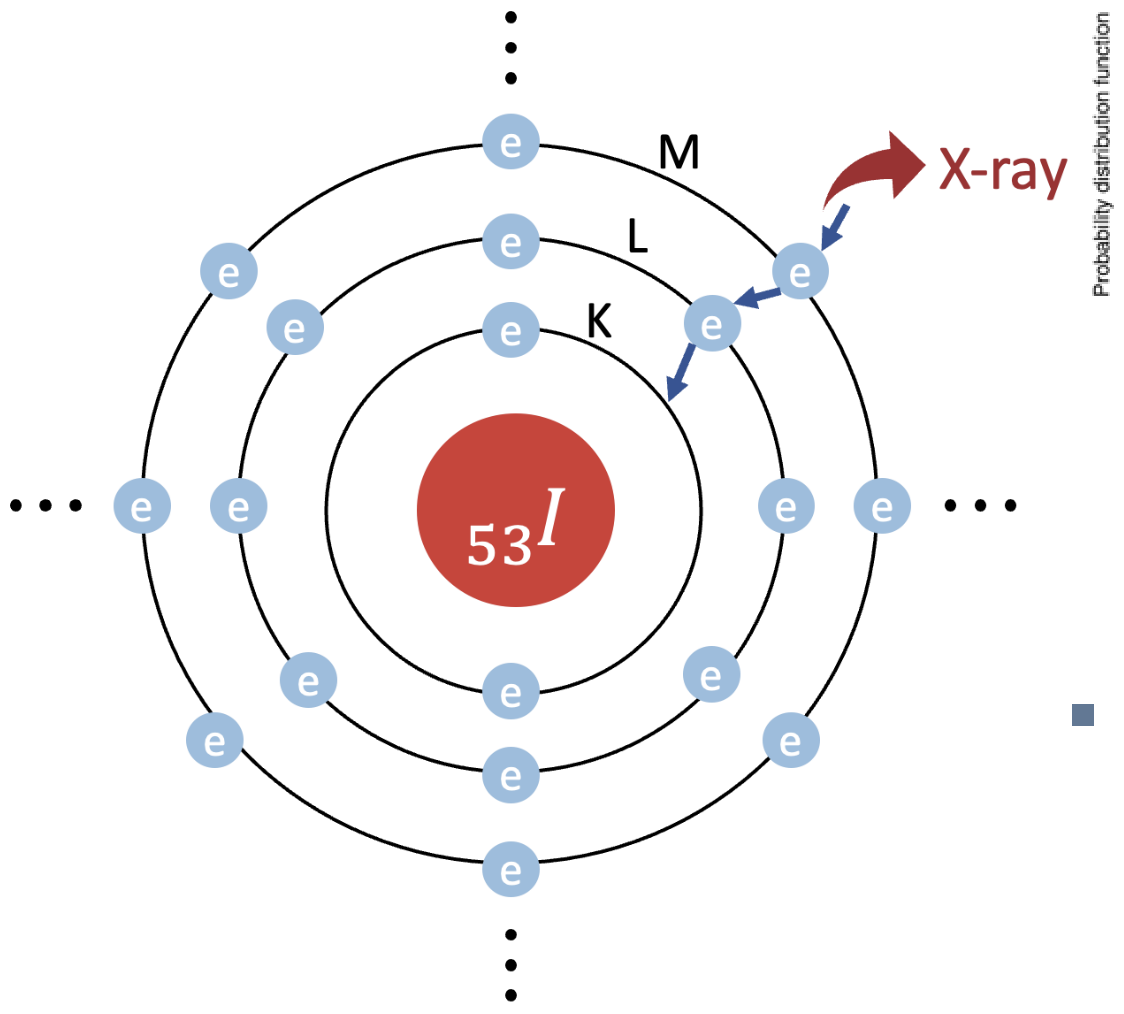
Yujin Lee

HEP Center 2023 Winter Workshop
2023.12.27 ~ 2023.12.28 | 곤지암 리조트

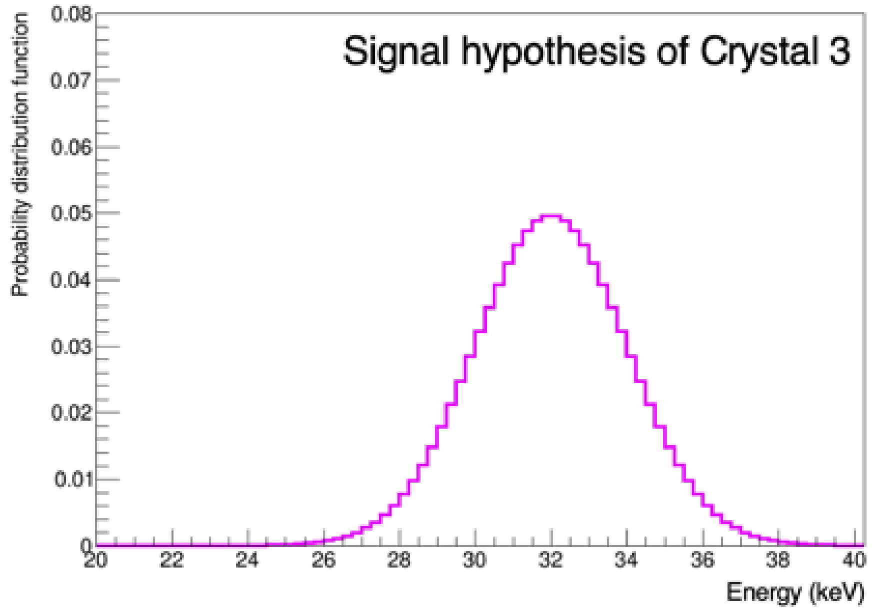
Violation of the Pauli Exclusion Principle (PEPV)

The forbidden electron transition in Iodine atom in NaI(Tl) crystals





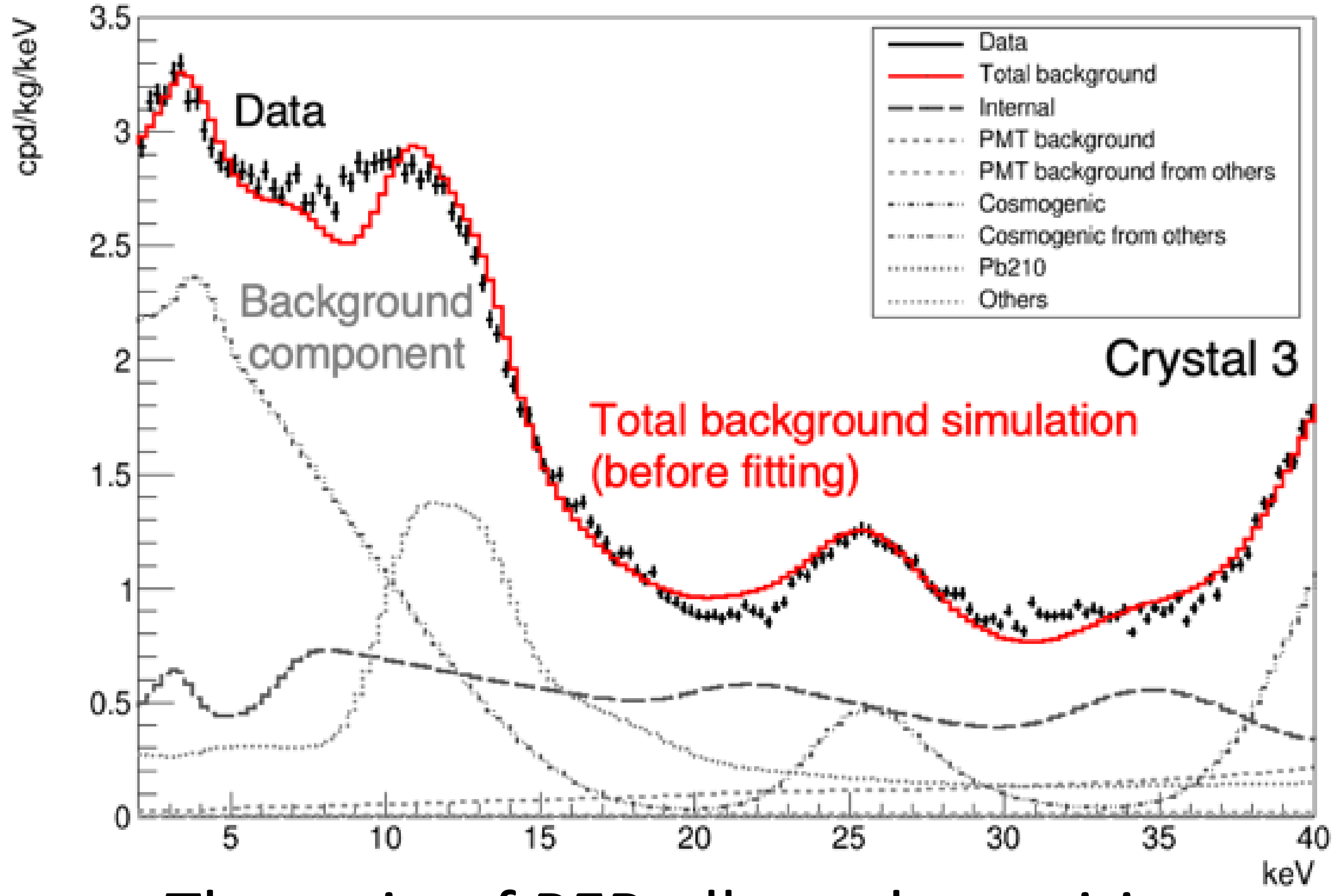
- An electron from the outer shell enters, resulting in three electrons in the K shell
- Through electron rearrangement, 32 keV of X-rays and Auger electrons are emitted



- PEPV lifetime

$$\tau_{PEPV} = \frac{\epsilon N t}{S}$$

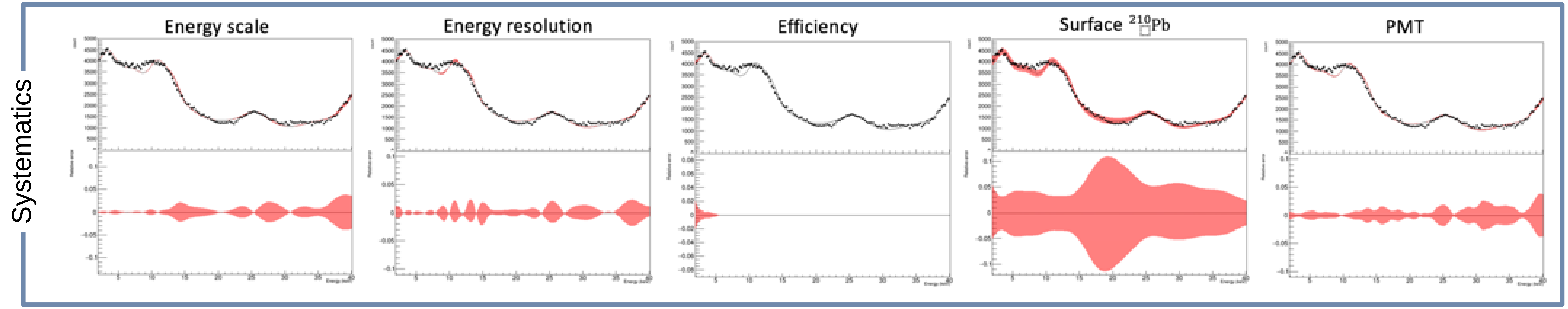
  - ϵ: the efficiency of the detector
  - N: the number of target atoms
  - t: the data collection time
  - S: the event counts of PEPV



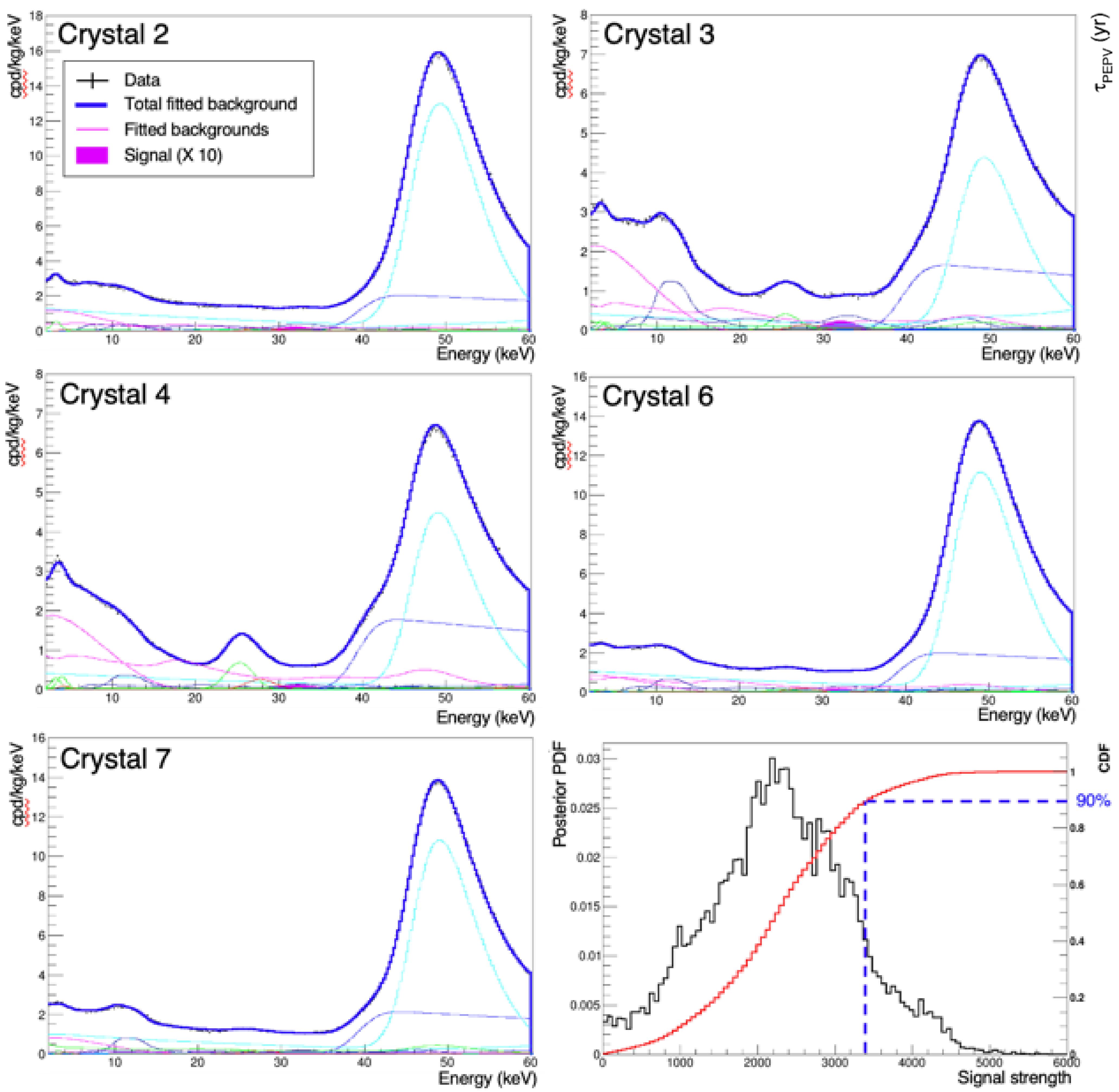
- The ratio of PEP-allowed transition to PEPV transition

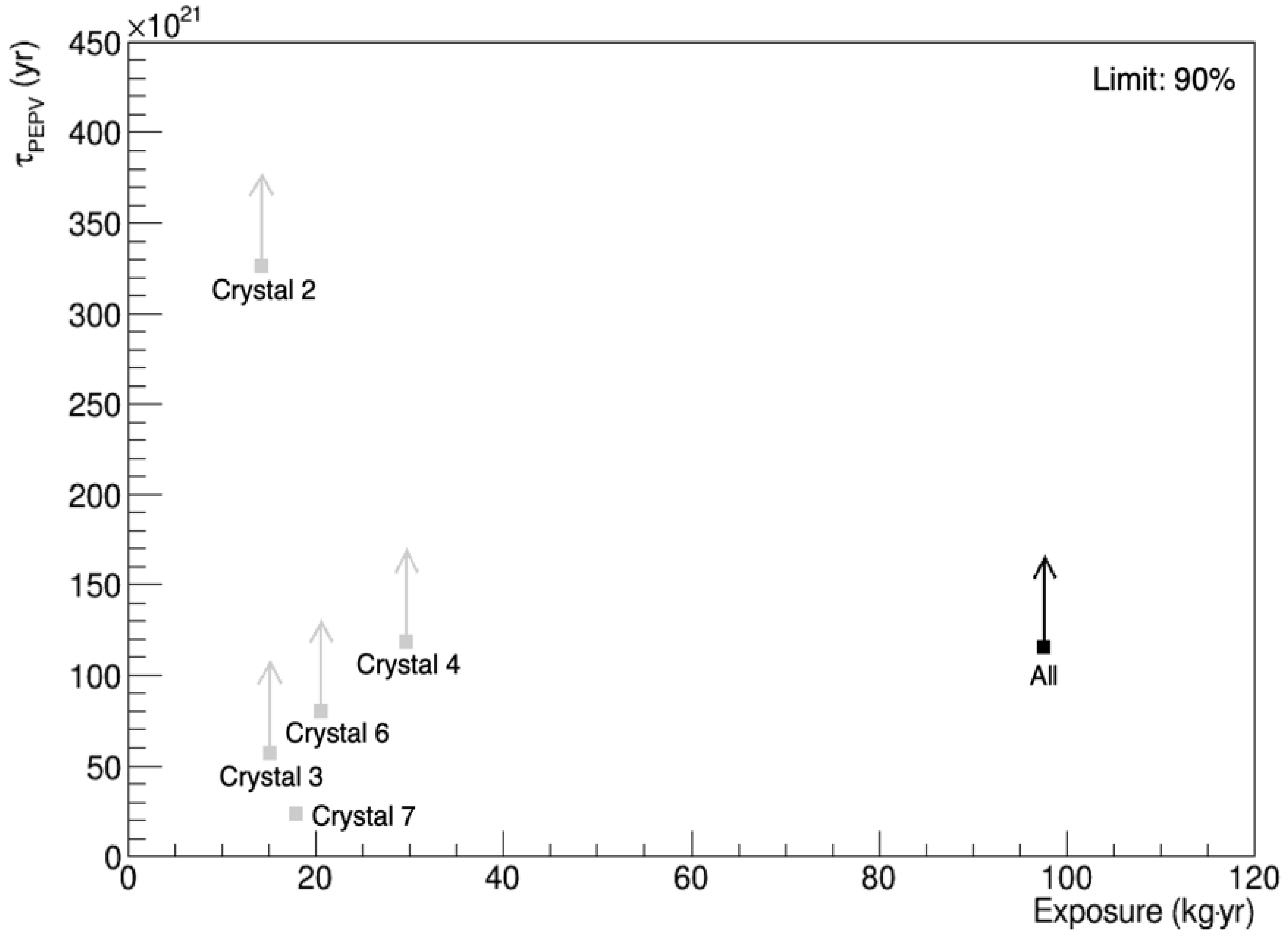
$$\delta_e^2 = \tau^0 / \tau_{PEPV}$$

  - τ^0: the PEP-allowed transition lifetime
  - $\tau^0 \sim 6 \times 10^{-17}$ s



The PEPV Lifetime and strength

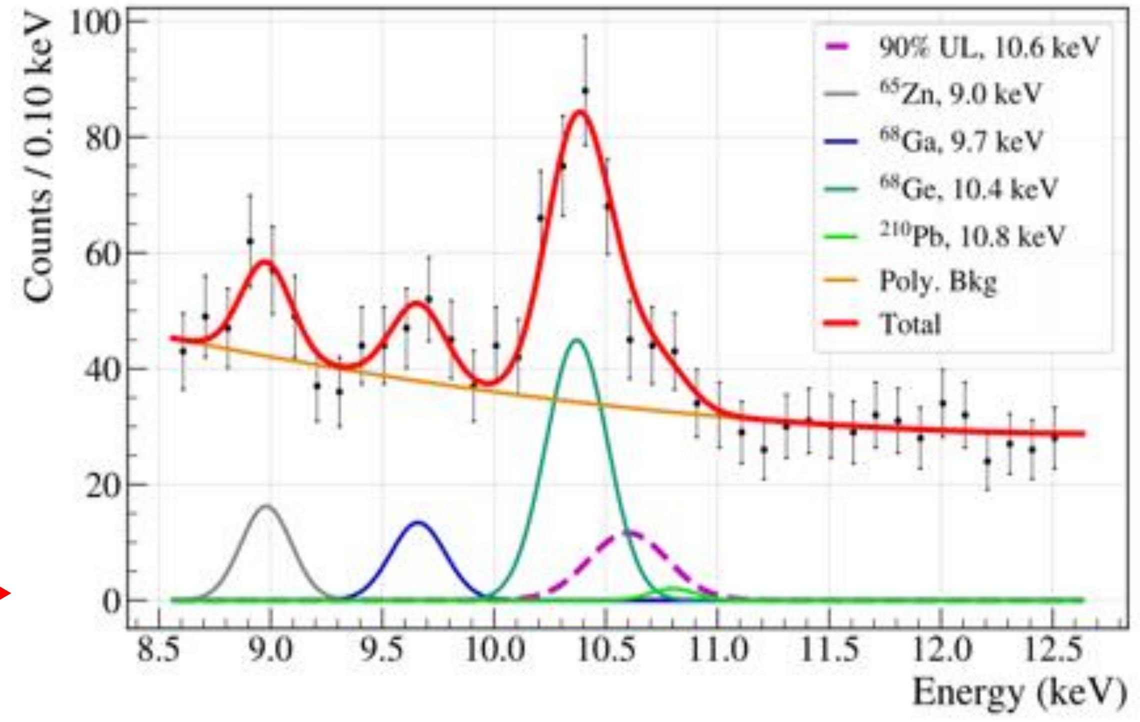




- No evidence for the PEPV hypothesis
- The upper limit of S < 3411 at 90% C.L.

$\tau_{PEPV} > 1.15 \times 10^{23}$ yr at 90% C.L.

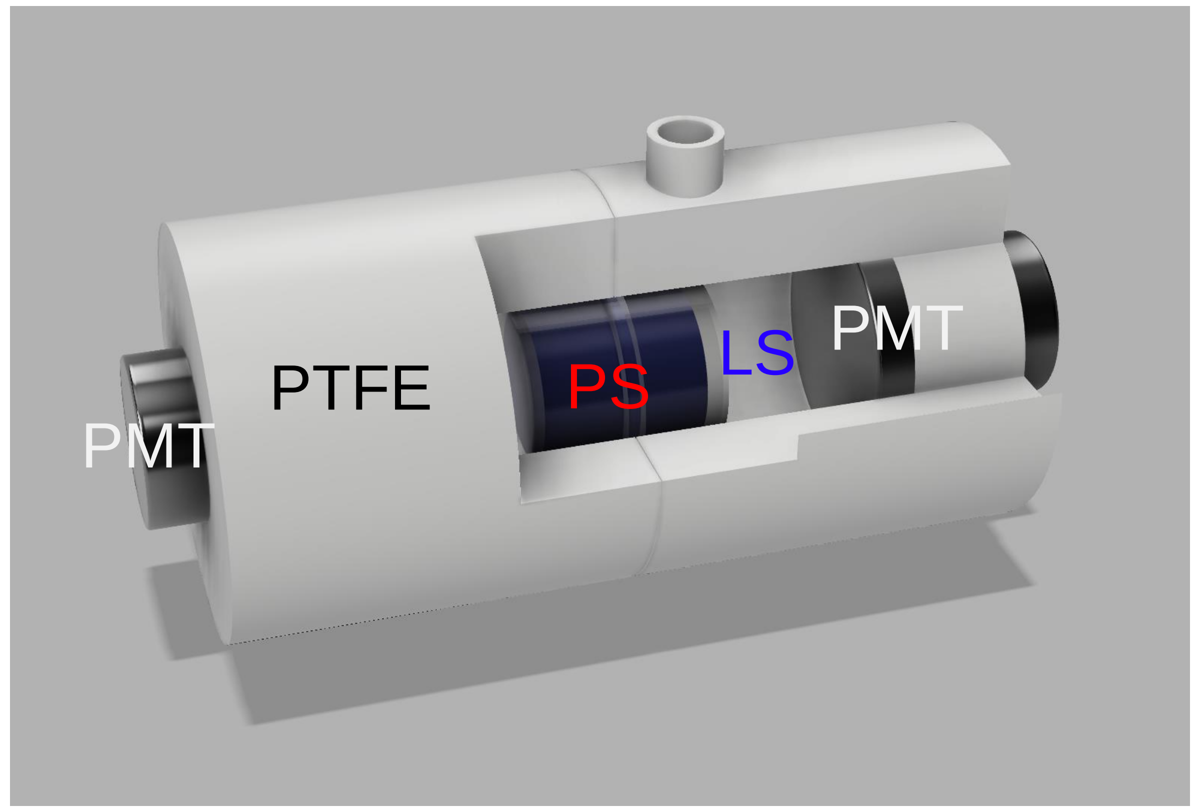
$\delta_e^2 < 1.65 \times 10^{-47}$ at 90% C.L.

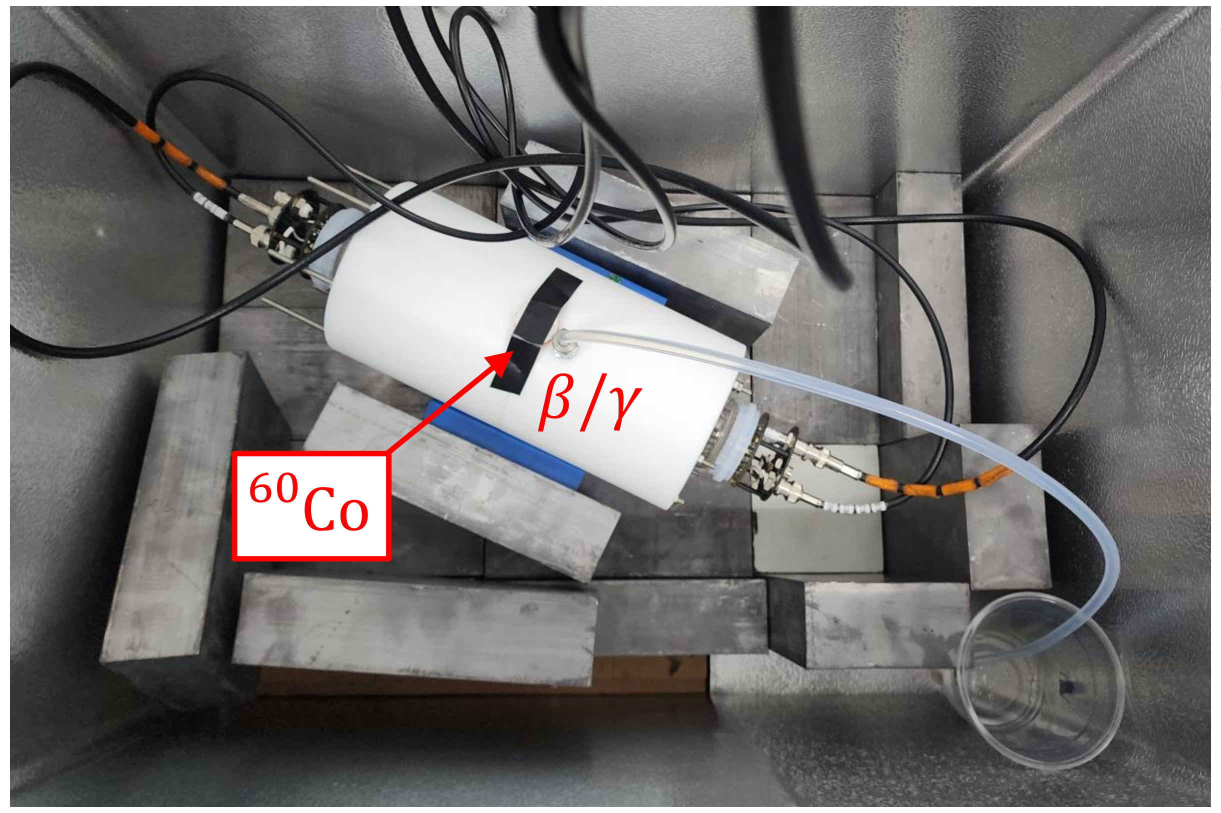


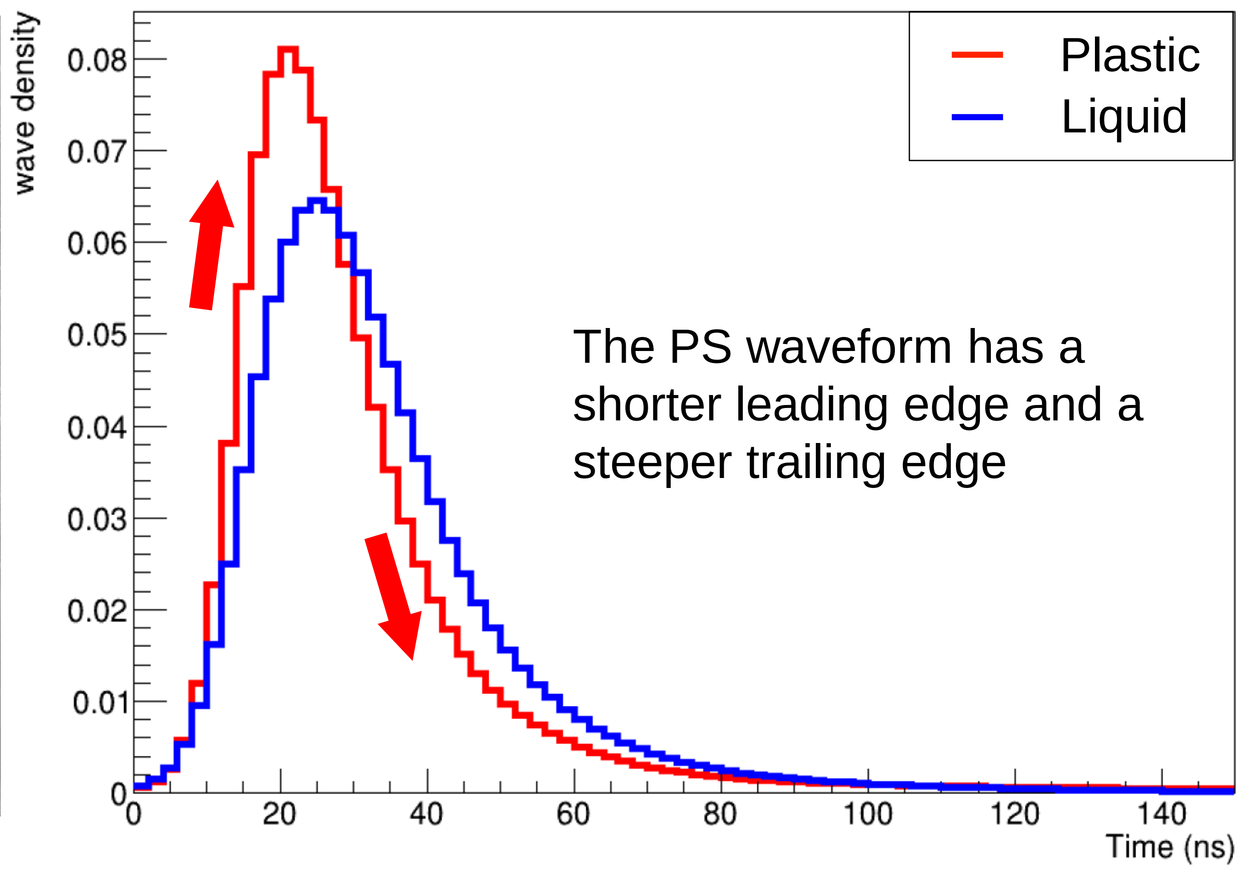
Experiment	Target	δ_e^{2*}	C.L.	year
Ramberg-Snow	Copper	$< 1.7 \times 10^{-26}$	95%	1989
VIP	Copper	$< 4.7 \times 10^{-29}$	95%	2009
VIP-2	Copper	$< 4.3 \times 10^{-30}$	95%	2022
S.R. Elliott et al.	Lead	$< 2.6 \times 10^{-39}$	99.7%	2012
DAMA	NaI (Tl)	$< 1.28 \times 10^{-47}$	90%	2009
MAJORANA	HPGe	$< 1.0 \times 10^{-48}$	90%	2023

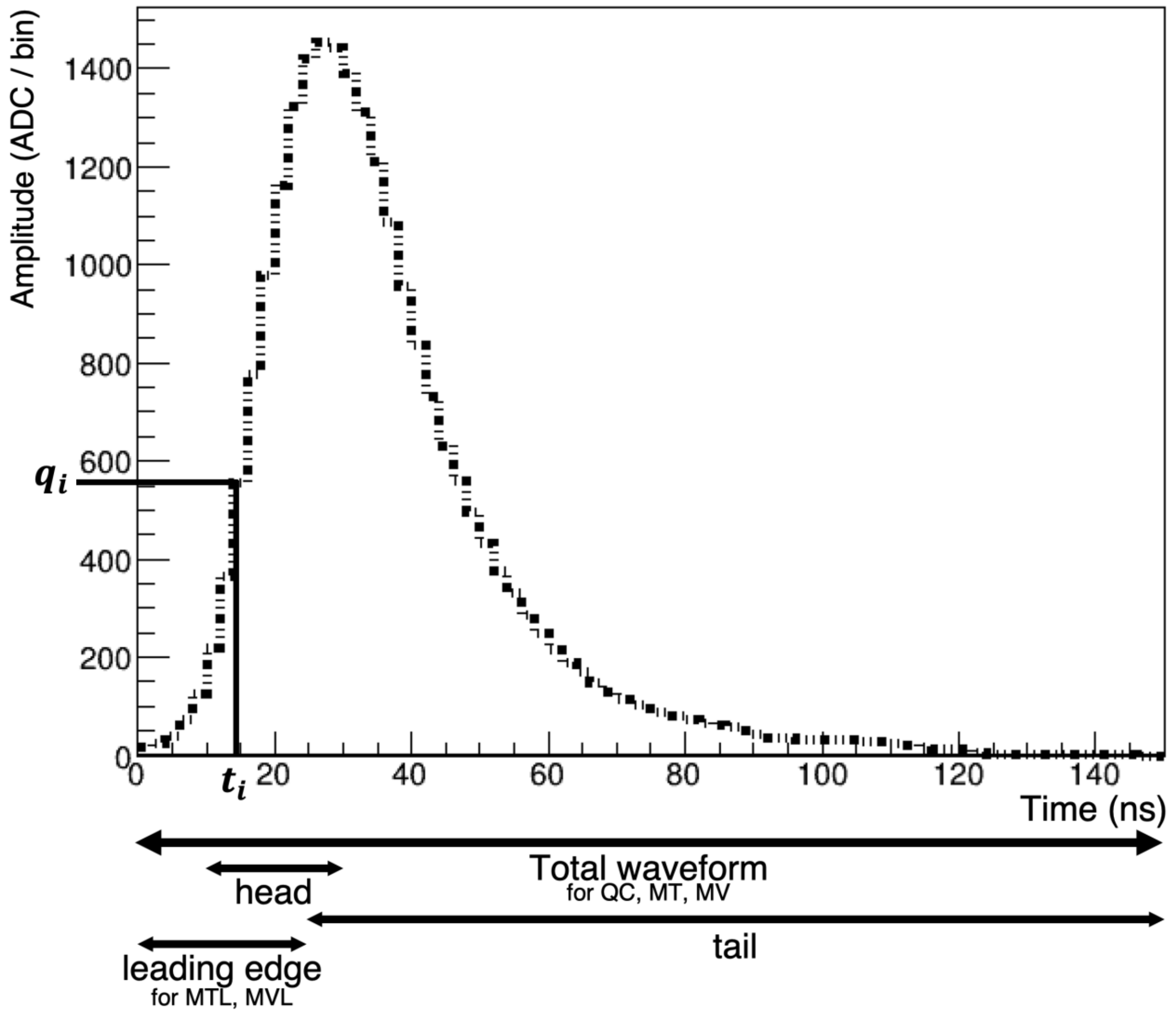
Pulse Shape Discrimination of Organic Scintillations

Phoswich detector with the plastic and liquid scintillators



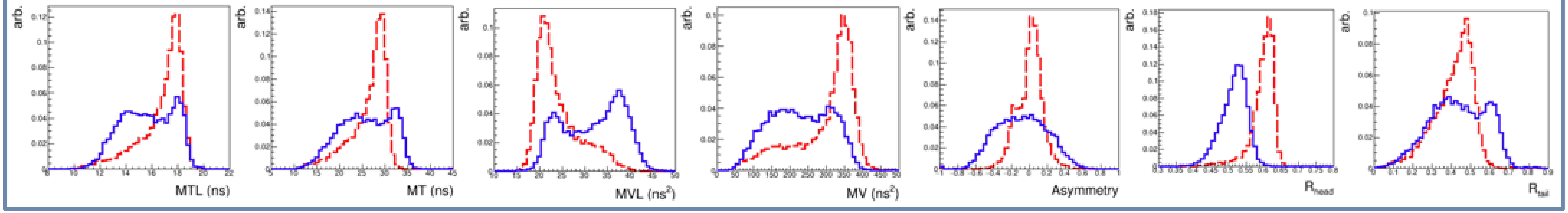






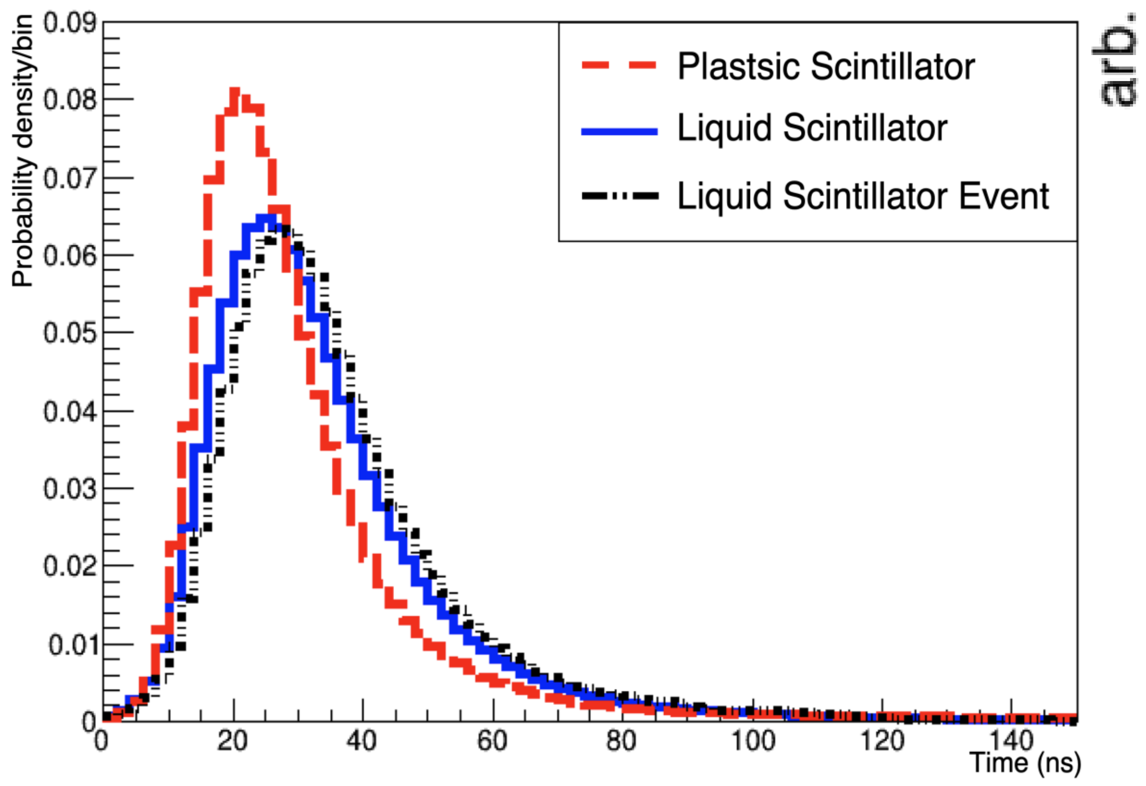
- Linear alkylbenzene (LAB) – based liquid scintillator & EJ-200 plastic scintillator
- These organic scintillators' signals are difficult to discriminate due to their short decay times and similar characteristics
- Machine learning algorithm such as Boosted Decision Tree (BDT) can be used for classifying them

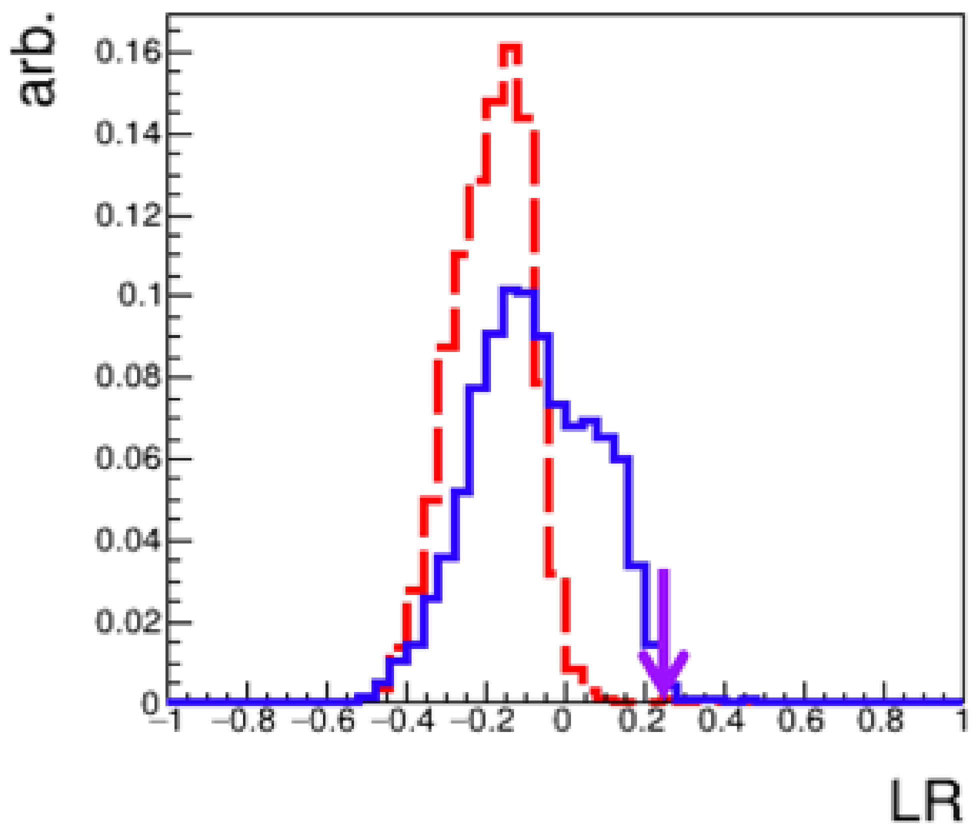
BDT variables



Phoswich detector with the plastic and liquid scintillators

BDT variables





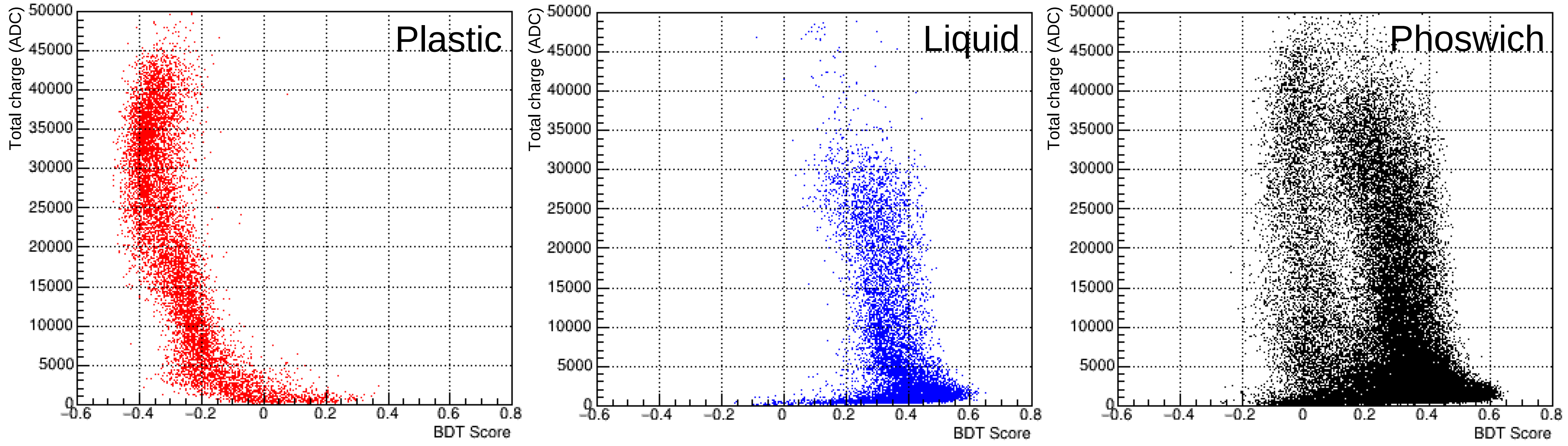
$$ln\mathcal{L}_{ps(ls)} = \sum_{0\,ns}^{150\,ns}\left(T_i - W_i + W_i ln\frac{W_i}{T_i}\right)$$

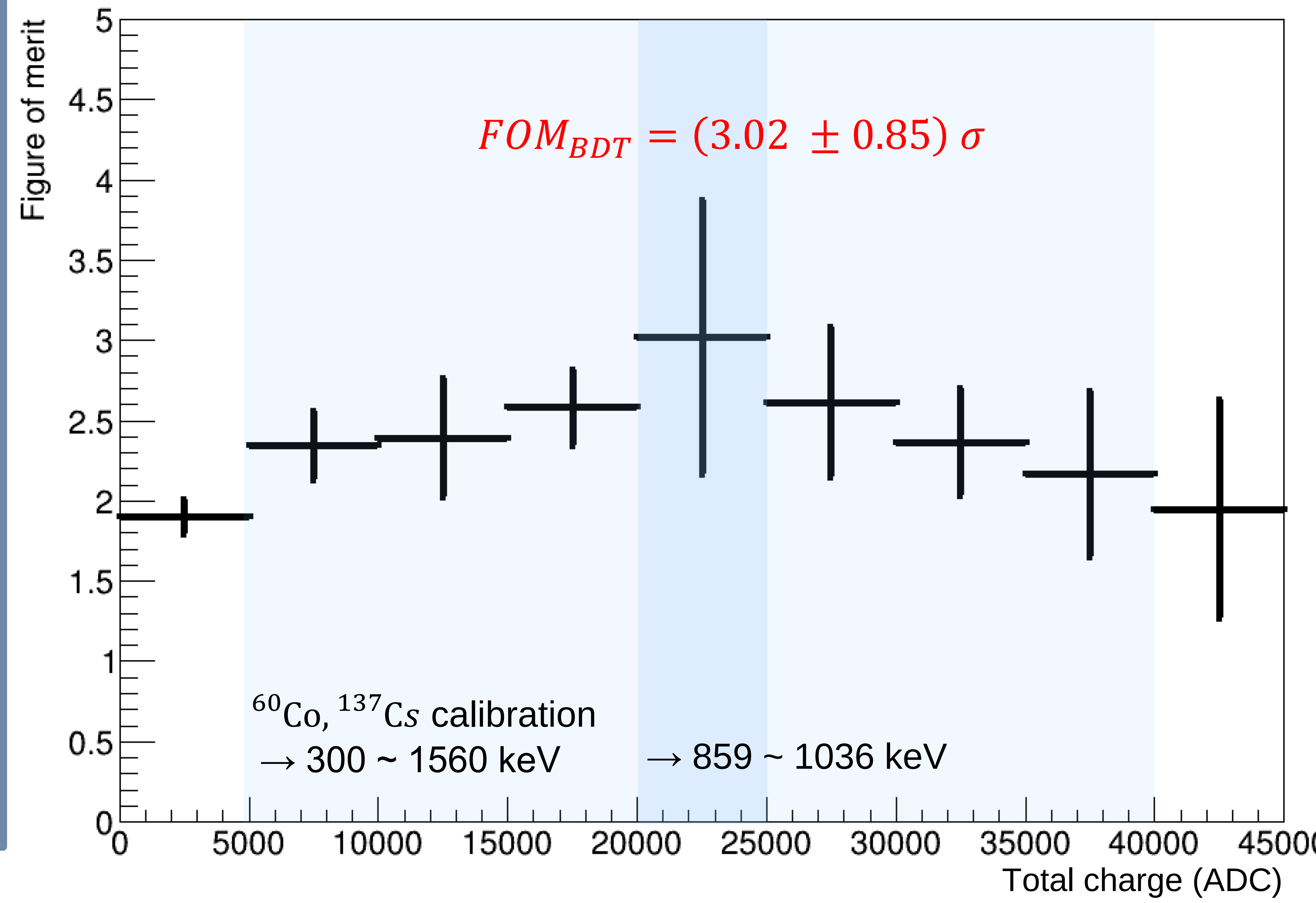
T_i: height of template (PDF)
W_i: height of waveform (PDF)

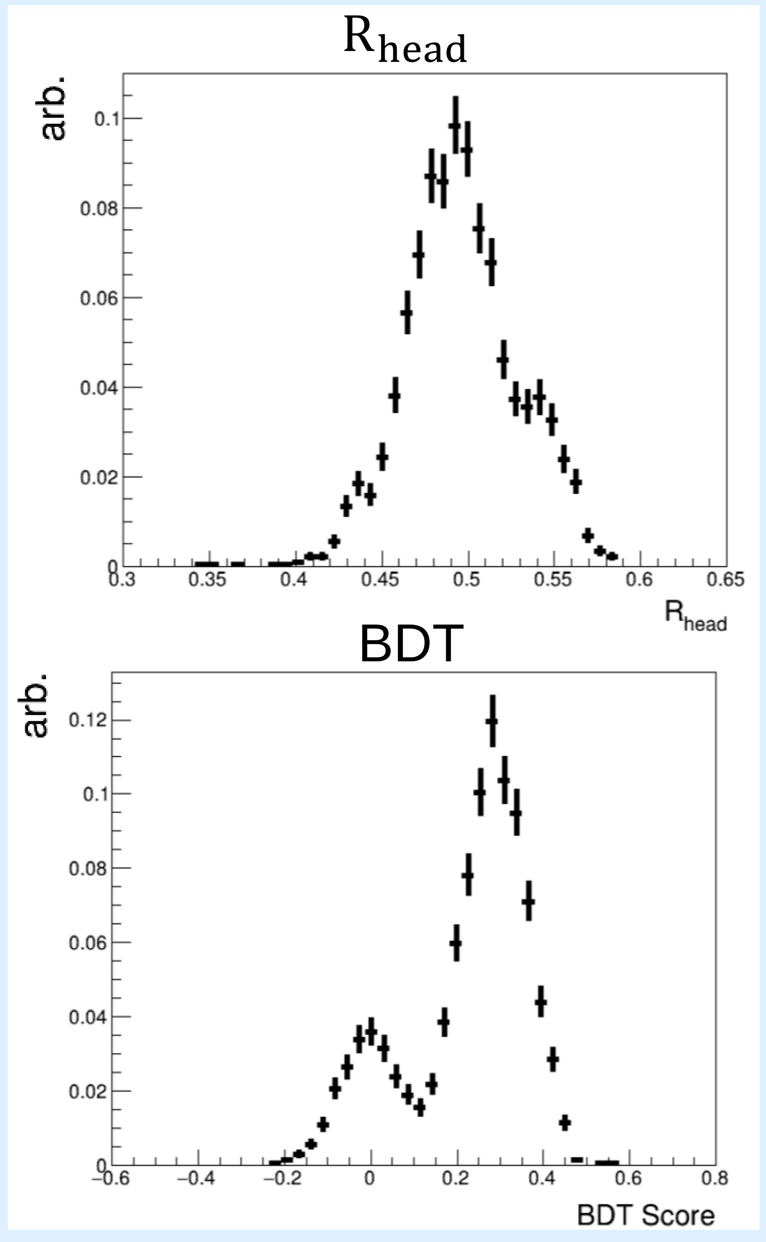
$$\boldsymbol{LR = ln\mathcal{L}_{ps} - ln\mathcal{L}_{ls}}$$

$$= \sum_i (T_{p,i} - W_i + W_i ln\frac{W_i}{T_{p,i}}) - \sum_i (T_{l,i} - W_i + W_i ln\frac{W_i}{T_{l,i}})$$

$$= \sum_i (T_{p,i} - T_{l,i} + W_i ln\frac{T_{l,i}}{T_{p,i}})$$







Summary

Violation of the Pauli Exclusion Principle (PEPV)

- **We explored the 32 keV PEP-forbidden electron transition in the iodine atoms of the NaI(Tl) crystal**
- **The Gaussian signal model, 45 background models, 5 kinds of systematics each crystal were used for fitting**
- **Evidence of this phenomenon was not found**
  - **A limit on the PEPV lifetime $\tau_{PEPV} > 1.15 \times 10^{23}$ yr at 90% C.L.**
  - **$\delta_e^2 < 1.65 \times 10^{-47}$ and $r_0 < 2.55 \times 10^{-18}$ cm at 90% C.L.**
- **We plan to continue further studies using the final data set and unused crystals**

Phoswich Detector

- **A phoswich detector using plastic and liquid scintillators, distinguishing these two kinds of signals with BDT**
- **The separation power reaches up to 3.02 σ with eight BDT variables, including likelihood parameter**
- **The purification of LS to enhance the light attenuation length and gamma/neutron separation using DIN-based LS are planned**

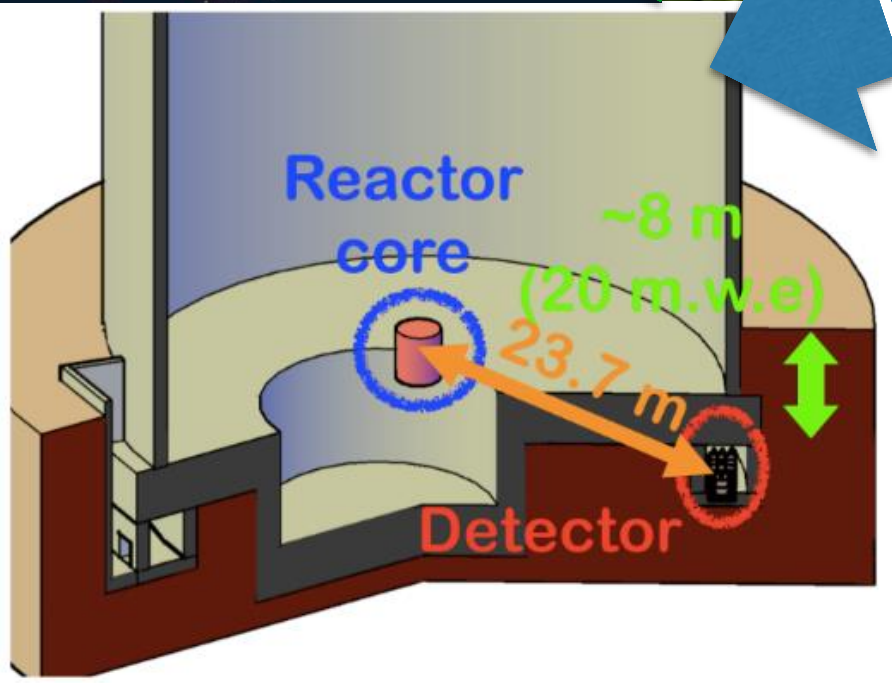
2023 Research Summary

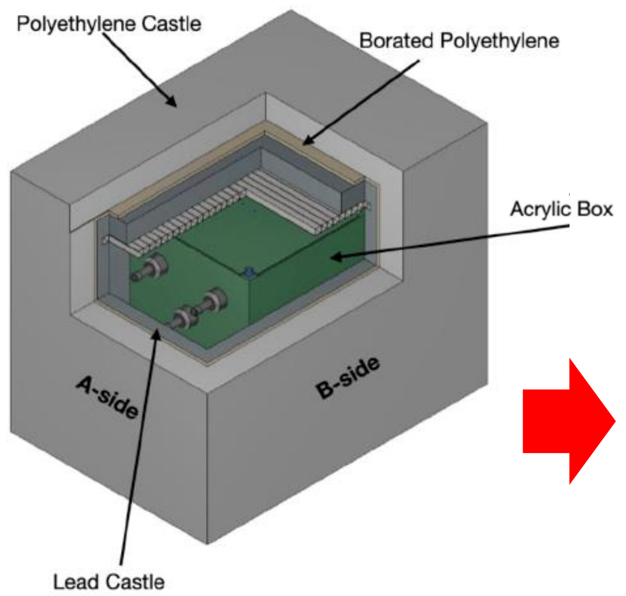
Byoung-cheol KOH

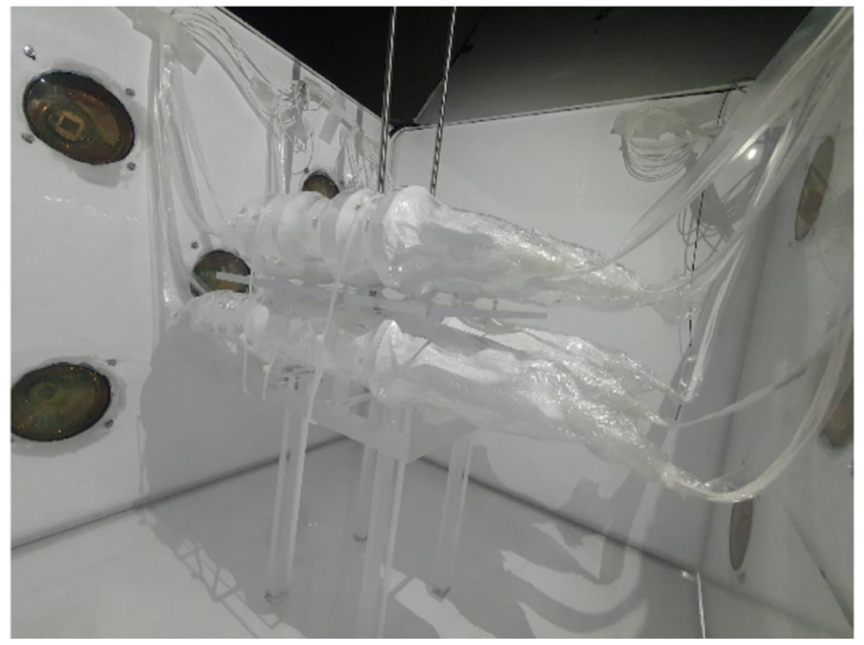
HEP Center 2023 Winter Workshop
2023.12.27 ~ 2023.12.28 | 곤지암 리조트

About NEON Experiment

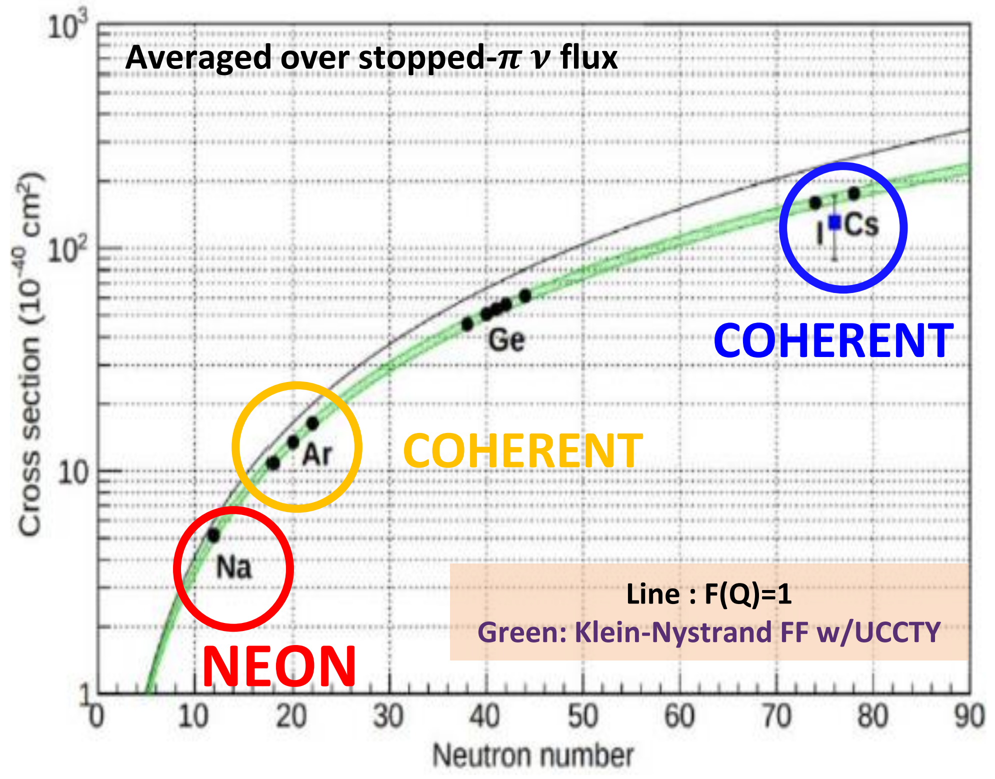
Site : Hanbit Nuclear Power Plant Unit 6 Tendon gallery
Reactor power : 2.815 GW_{th}
Neutrino($\bar{\nu}_e$) flux at NEON site :7.1 × 10^{12} $cm^{-2}s^{-1}$
Detector : NaI(Tl) Crystals, 16.7 kg (Phase-2)







- Measuring **C**oherent **e**lastic **n**eutrino-**n**ucleous **s**cattering (**CEvNS**) has not been achieved by **reactor neutrino source & NaI(Tl) crystal.**
- **N**eutrino **e**lastic scattering **o**bservation with **N**aI (**NEON**) is an experiment that aims to observe CEvNS using reactor antineutrinos.
- **Neutrinos** are produced in **beta decays** of fission fragments.
- **Single flavor** ($\bar{\nu}_e$, electron anti-neutrino)
- High flux : 10^{12}~10^{13} $\nu/\text{cm}^2 s$
- E_ν< 10 MeV → **fully coherent** regime
- Clean in background, active and passive shielding
- **Recoil energy** is less than **few keV**.
- **Signal quenched** → Require **very low threshold**



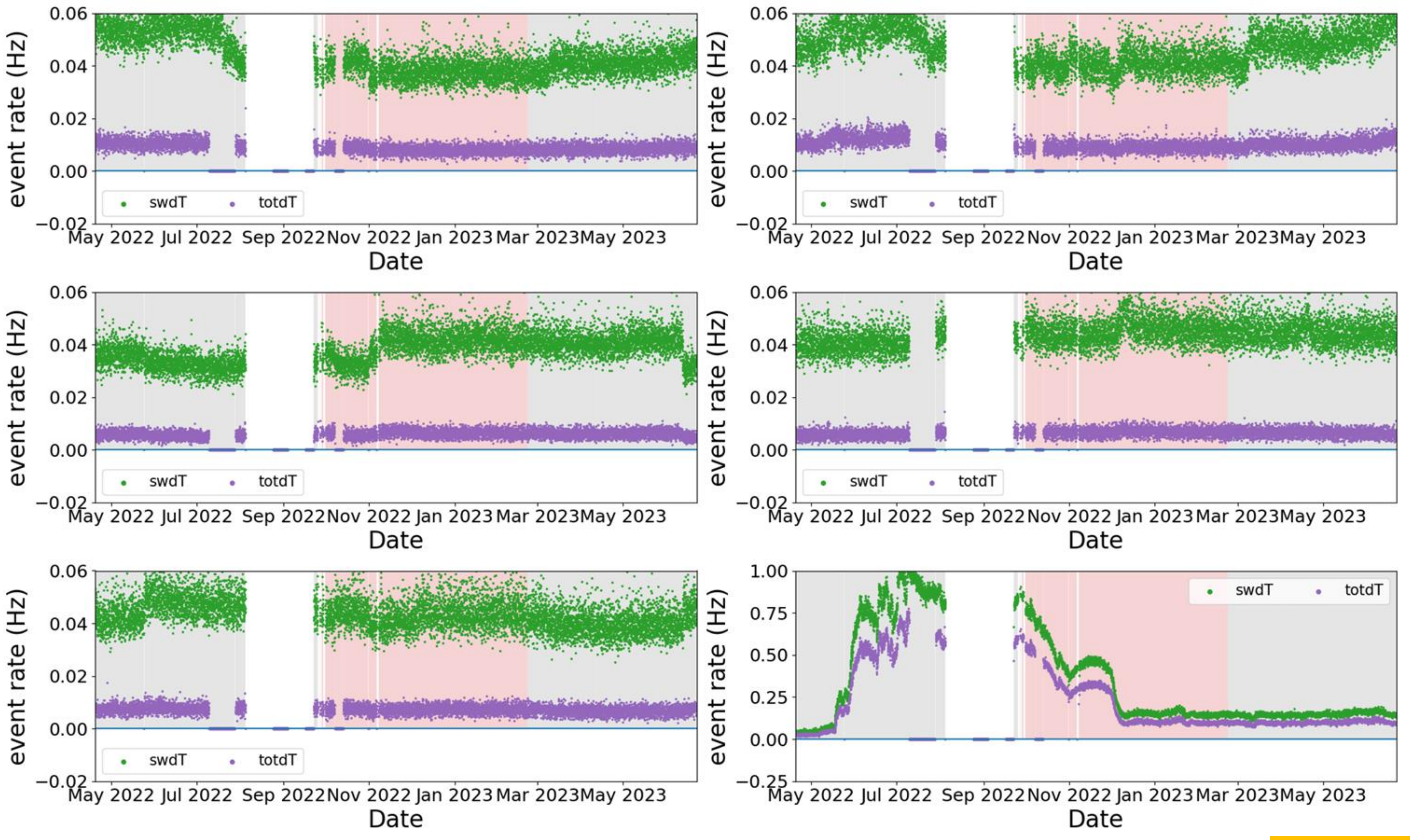
[differential cross section]

$$\left\langle \frac{d\sigma}{dT} \cong \frac{G_F^2}{2\pi} M \left[2 - \frac{MT}{E^2}\right] \frac{Q_W^2}{4} F^2(Q) \rightarrow \frac{d\sigma}{dT} \propto N^2 \right\rangle$$

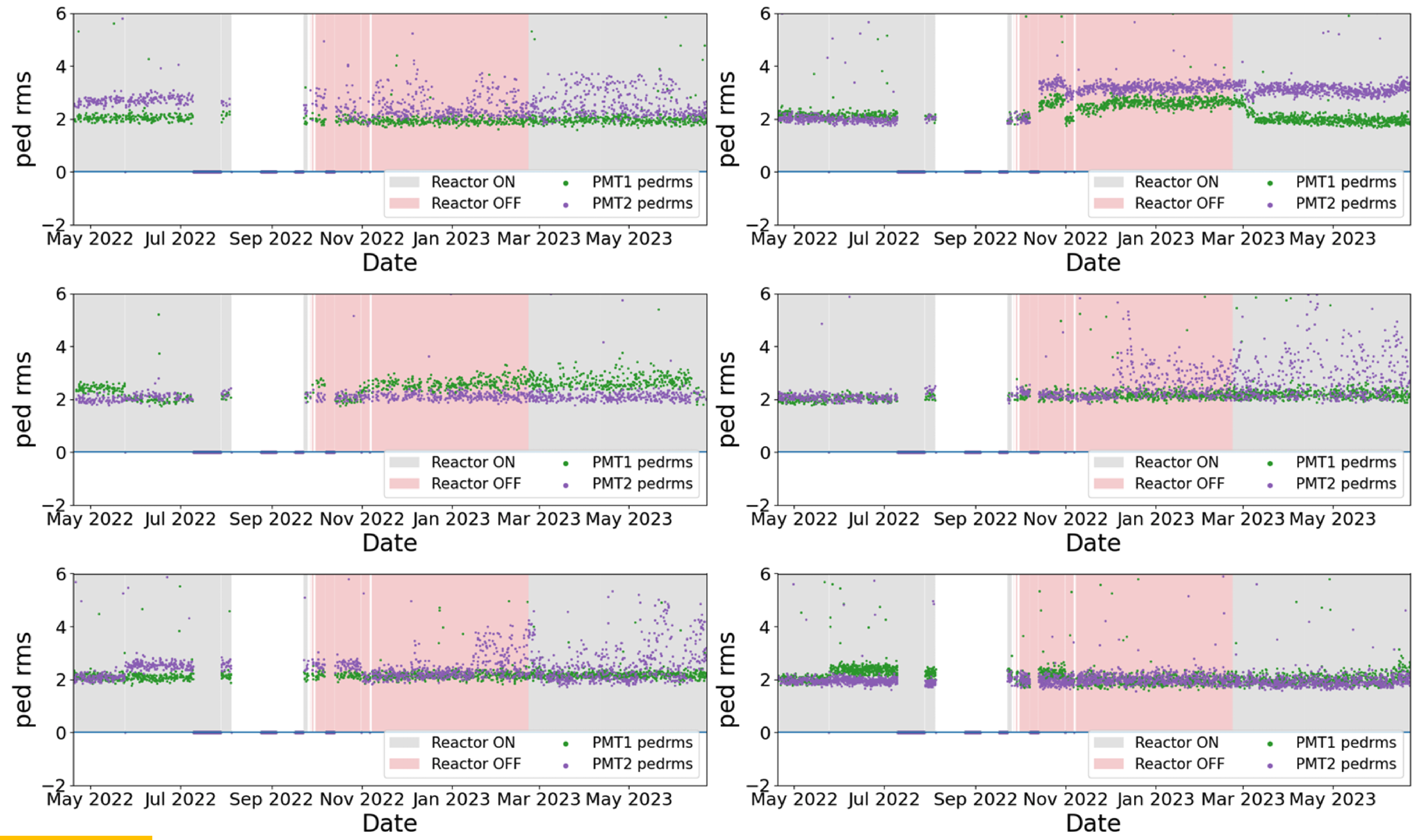
G_F : Fermi constant
T: nuclear recoil
M: mass of nucleus
Q= momentum transfer
$Q_W^2) \sim N^2$: weak nuclear charge
$Q_W = (1 - 4sin^2\theta_W)Z - N)$
$F^2(Q)$: Form factor (F= 1, full coherence)

NEON data acquisition(daq) monitoring

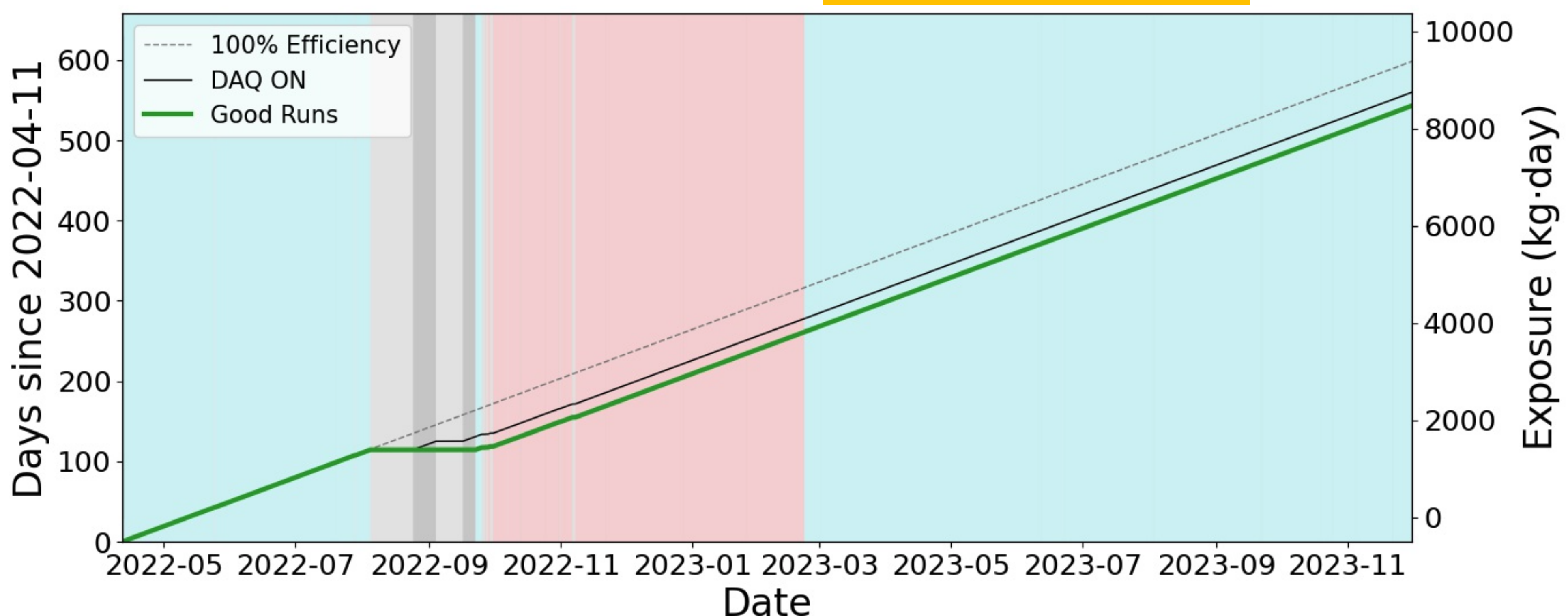
DAQ event rate monitoring

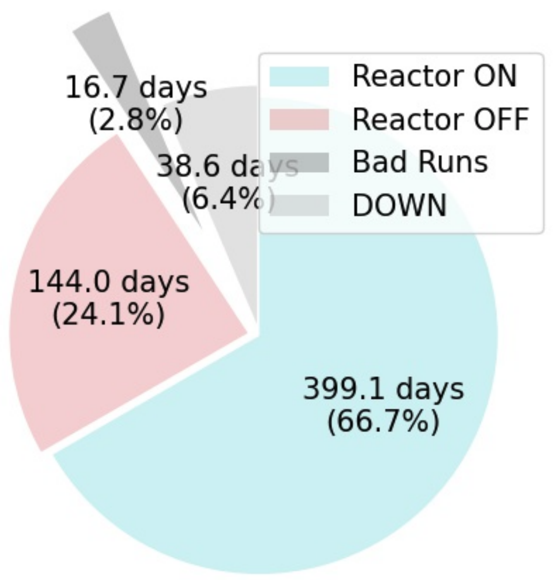


RAW data pedestal RMS monitoring



NEON exposure

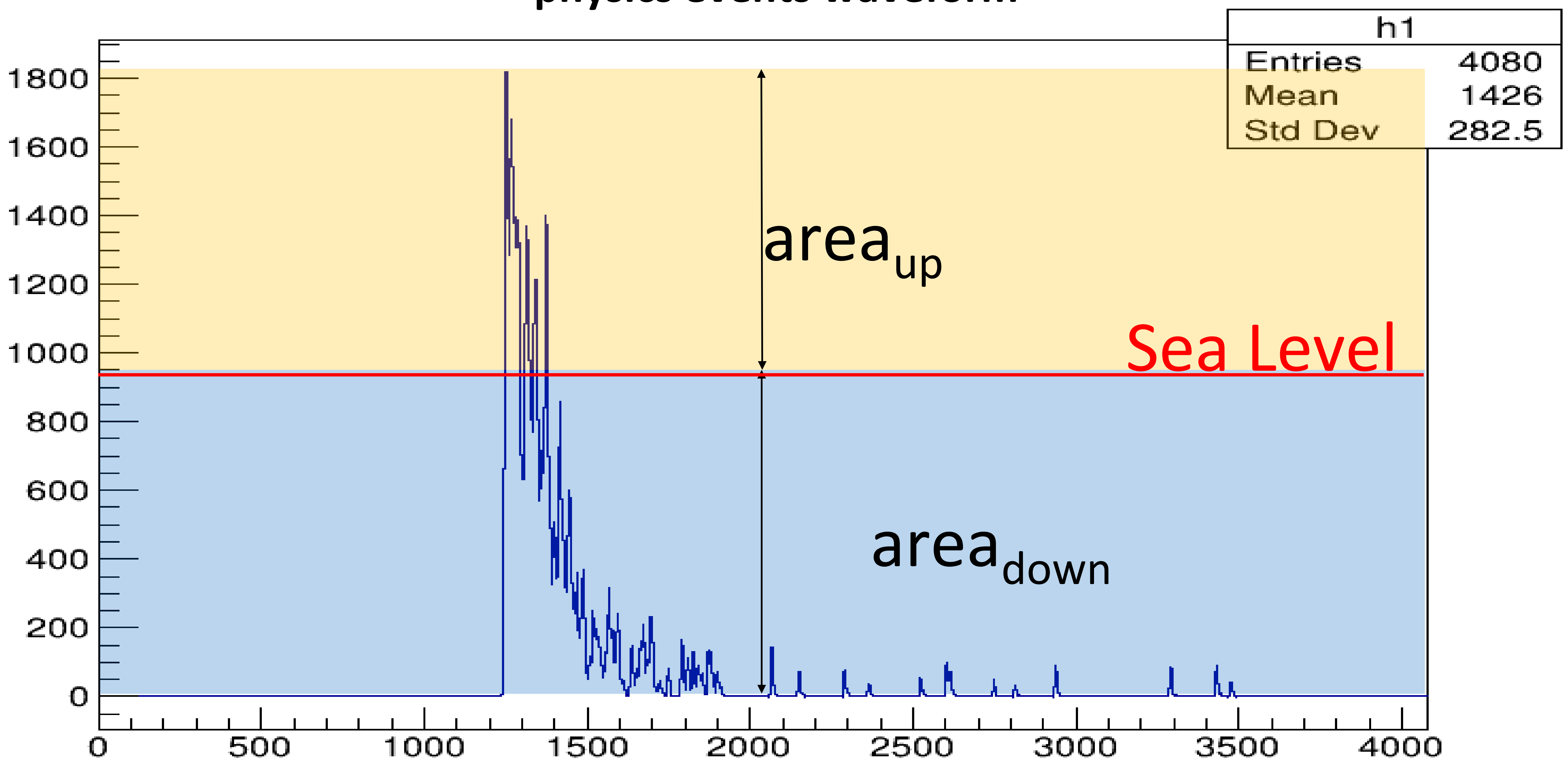




Variable Development for PMT noise

One of the variables currently under development

physics events waveform



[Sea-Level ratio(SLr) parameter & SLrTime Parameter]

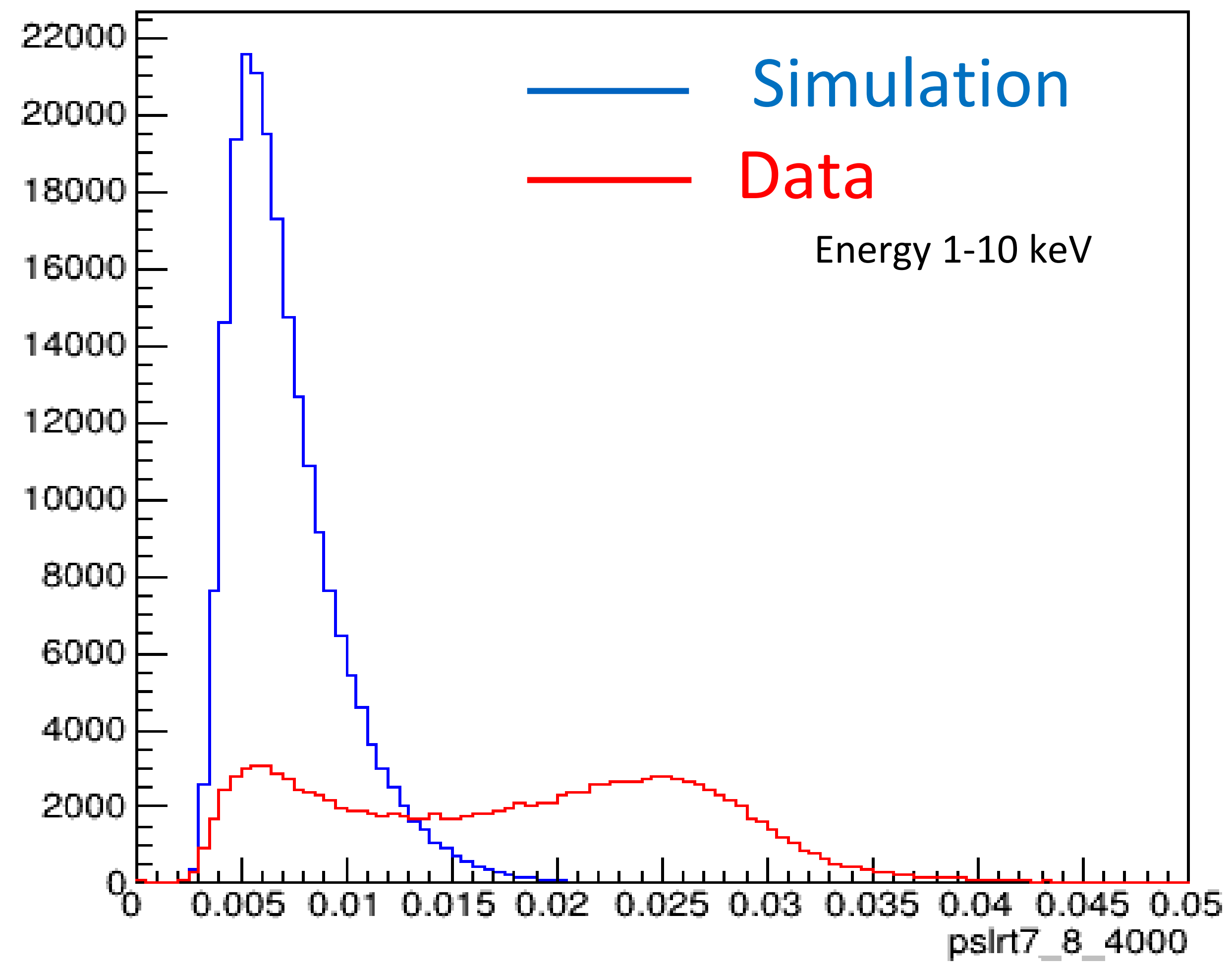
1) Calculate Waveform maximum bin height(Fmax),

2) Sea = $\text{Fmax} \times \frac{n}{m}$ (ex. ½, ¼ …)

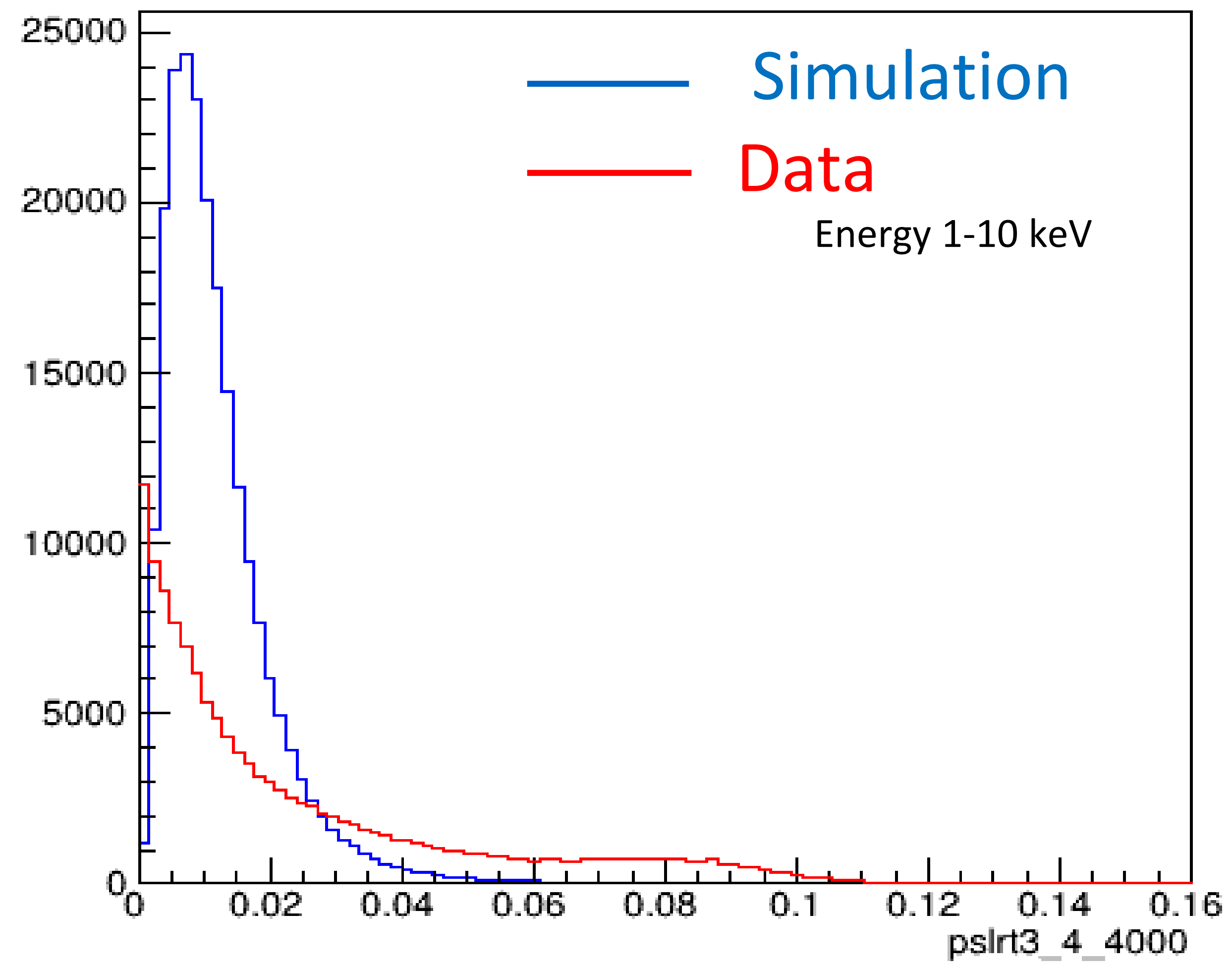
3) $\text{SL ratio [SLr]} = \frac{\text{area over sea level(areaup)}}{\text{area under sea level(areadown)}}$

4) $\text{SLr Time [SLrT]} = \sum_{o}^{time} \frac{\text{bin height over SL} \times \text{bin time}}{\text{bin height under SL} \times \text{bin time}}$

PMT SLr 7/8 4000 ns distribution

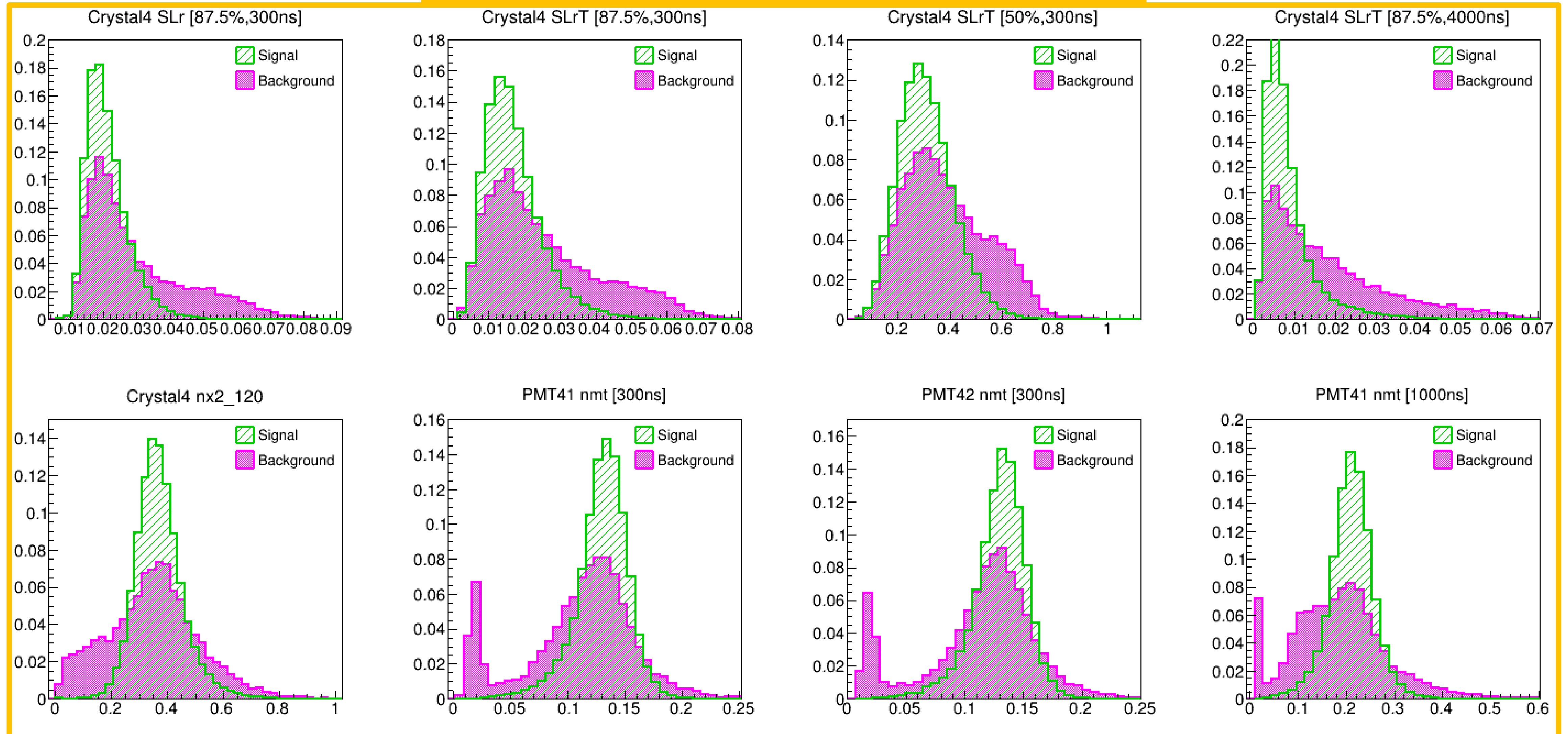


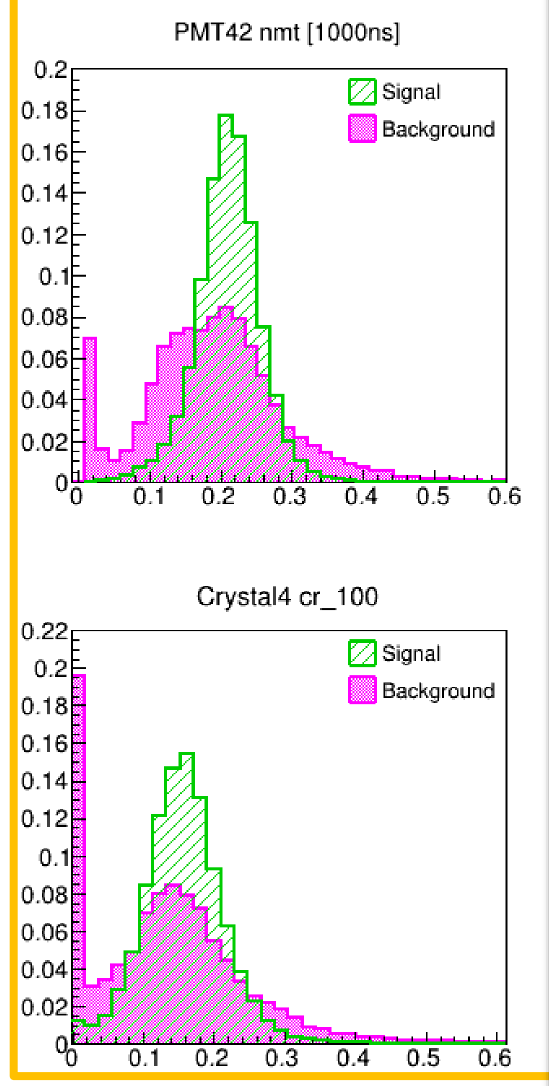
PMT SLrT 3/4 4000 ns distribution



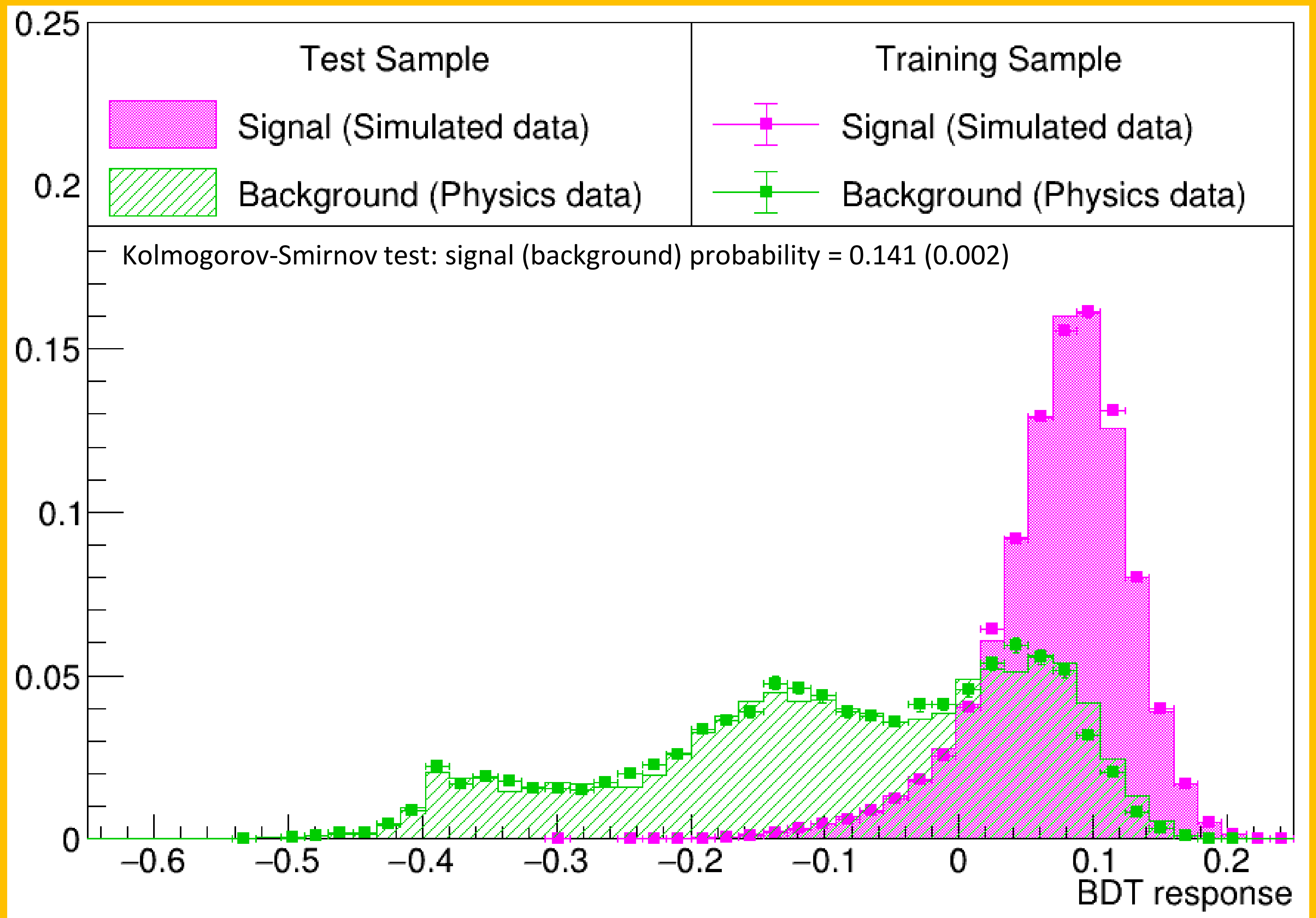
Boosted Decision Tree (BDT) Training for PMT noise

Input Variables for Machine learning

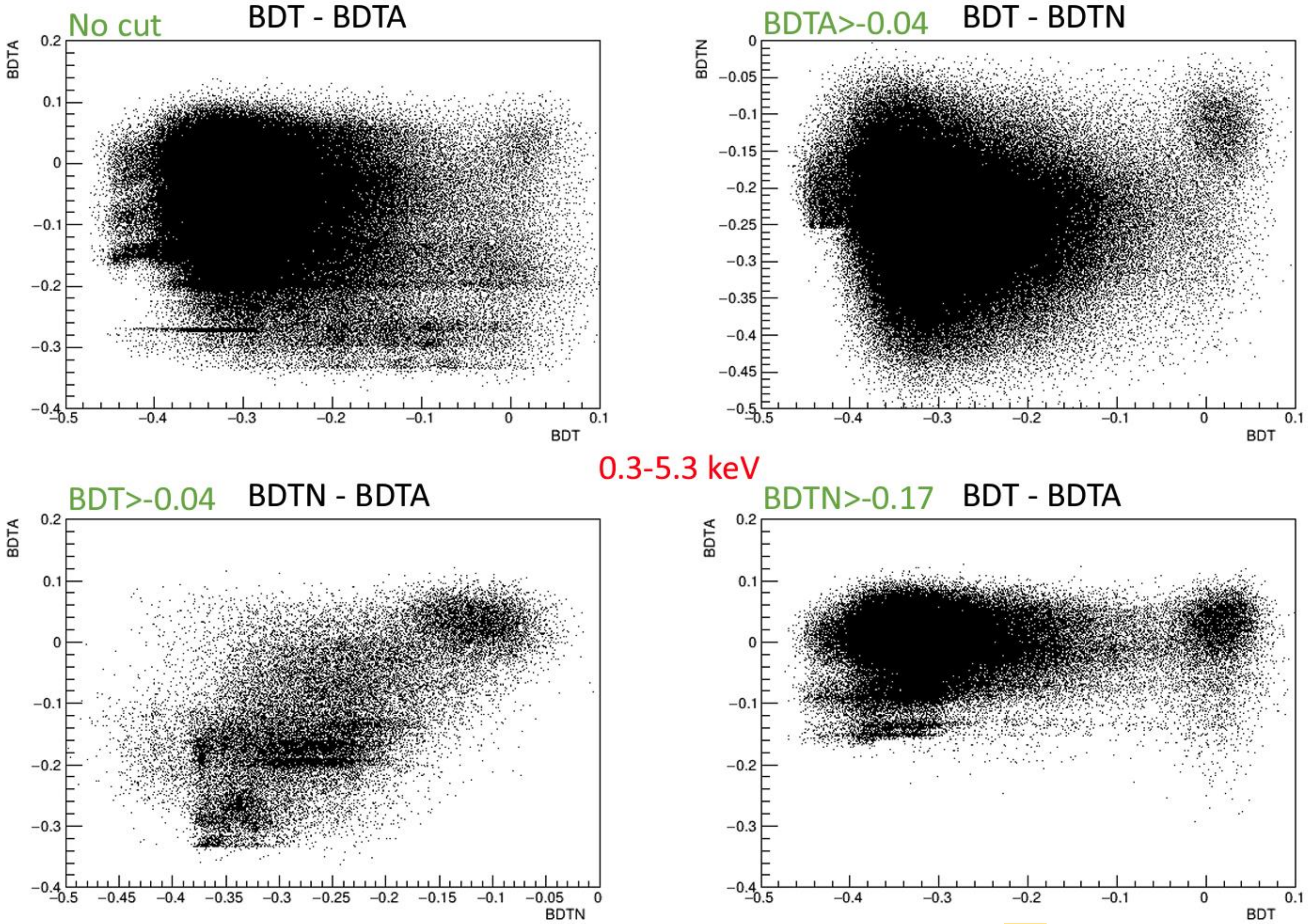




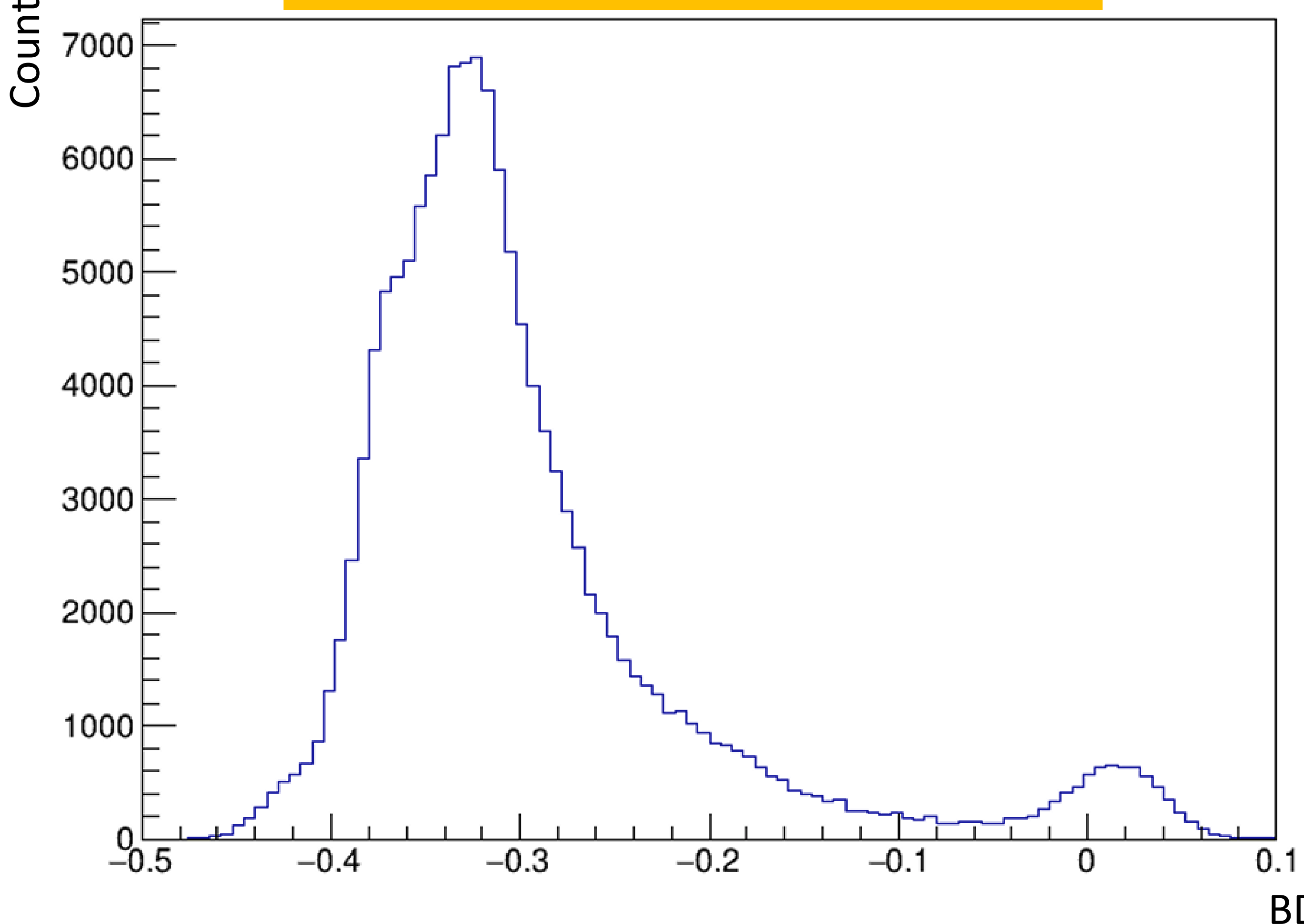
BDT training results



Applying previous (BDT,BDTA) and new bdt (BDTN) to NEON data

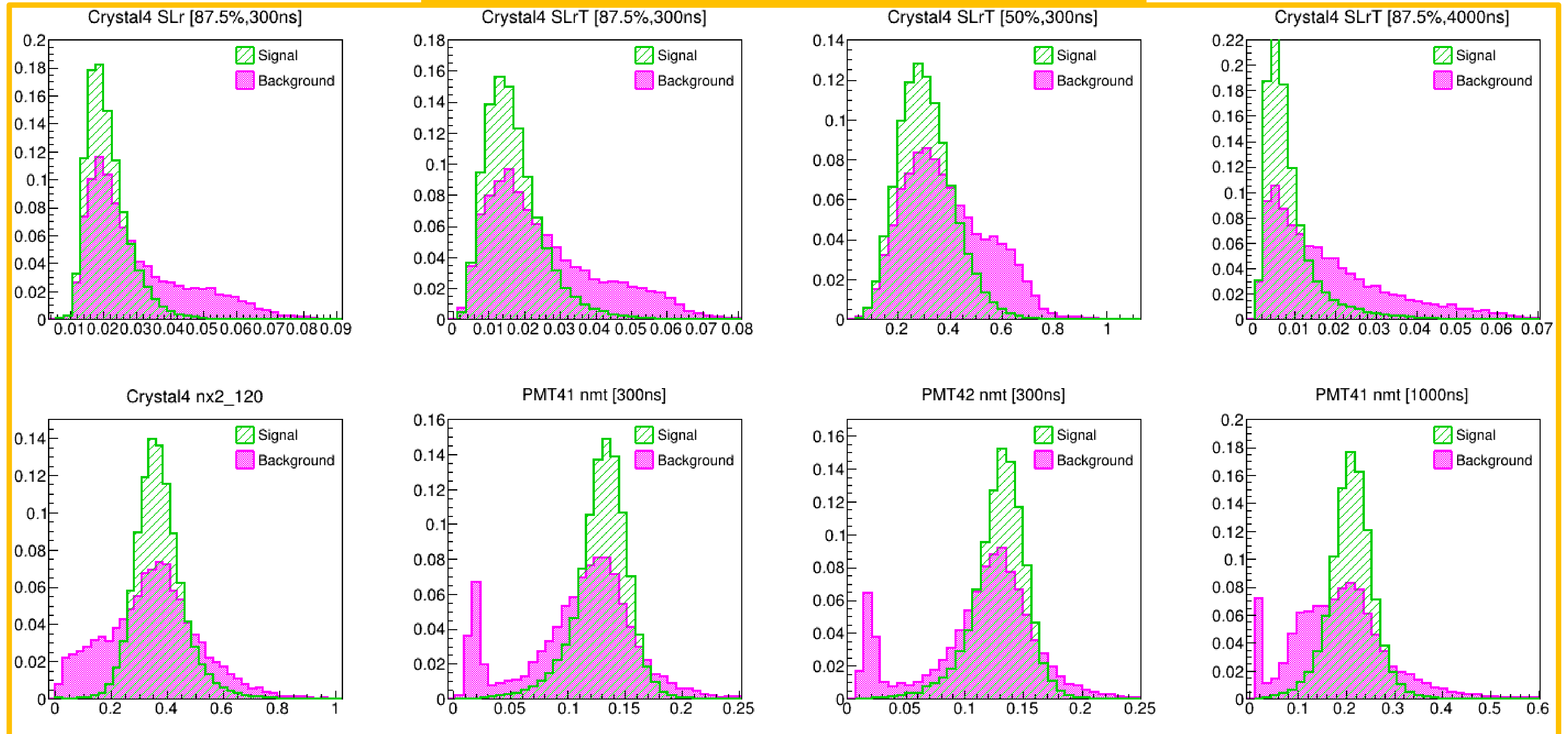


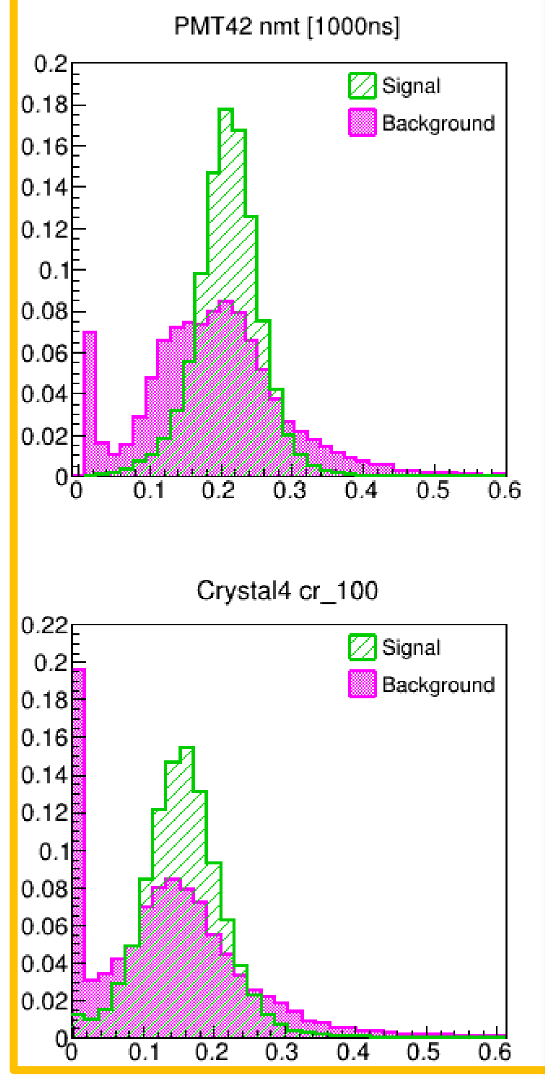
BDT histogram after BDT cut



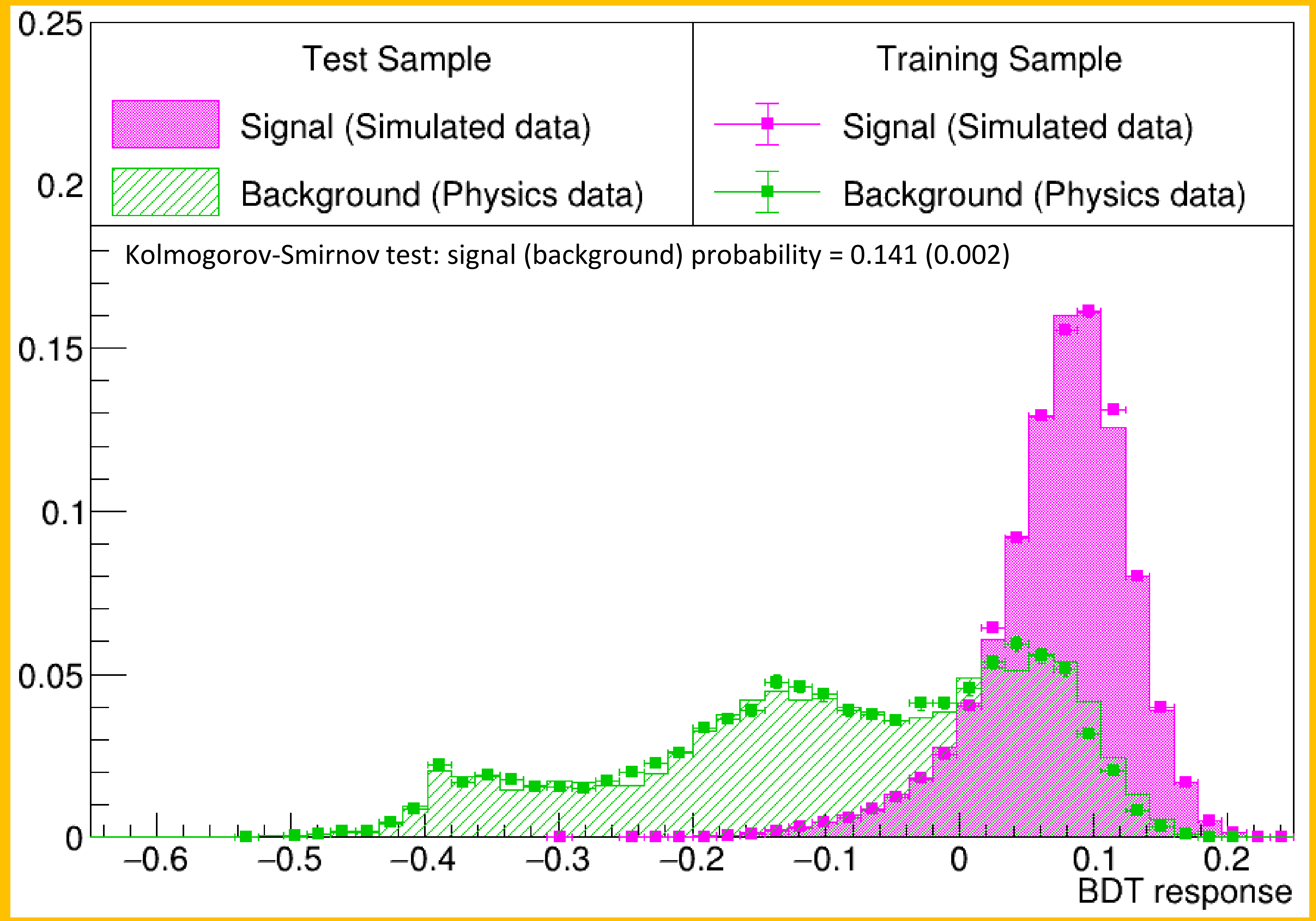
Boosted Decision Tree (BDT) Training for PMT noise

Input Variables for Machine learning

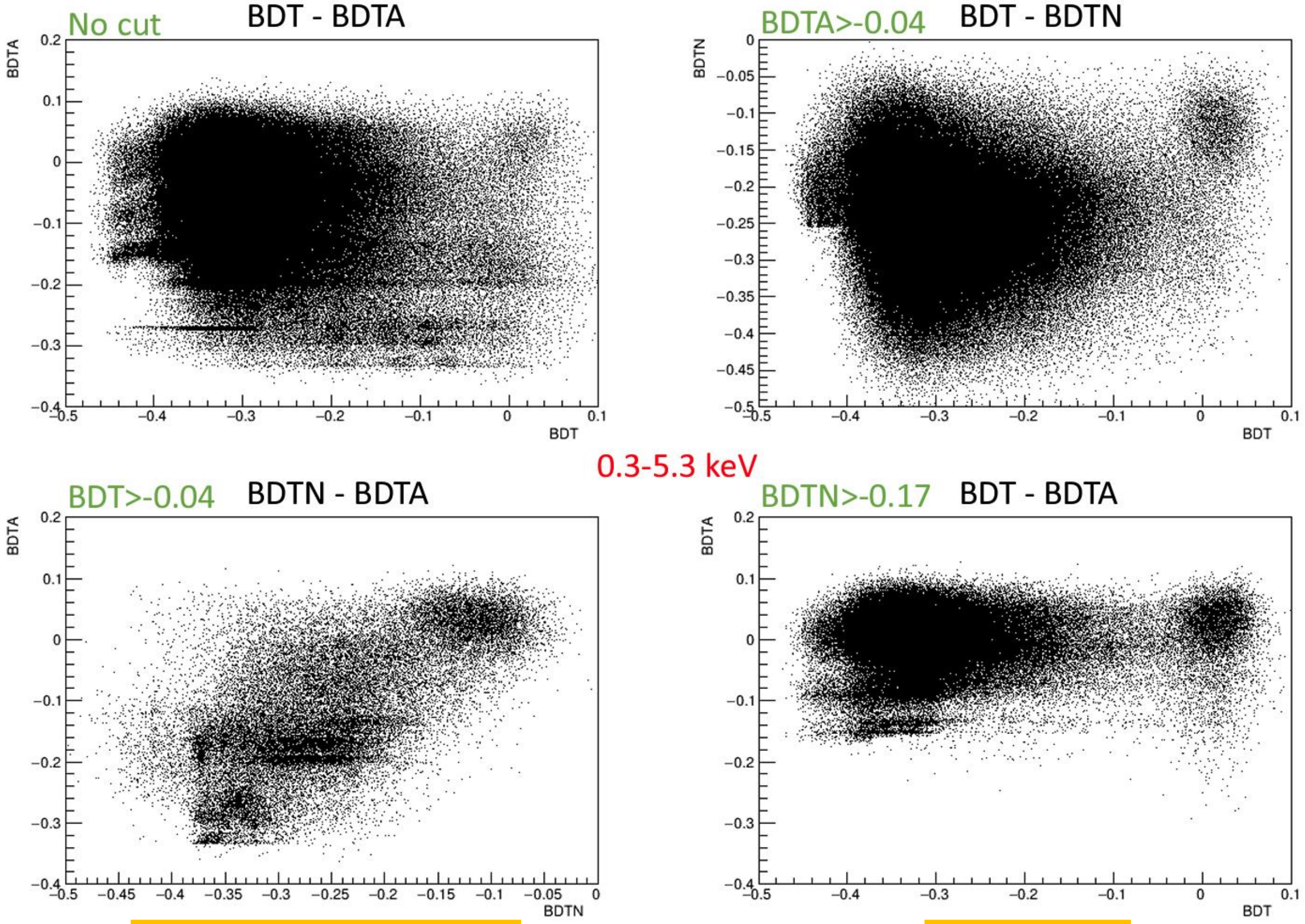




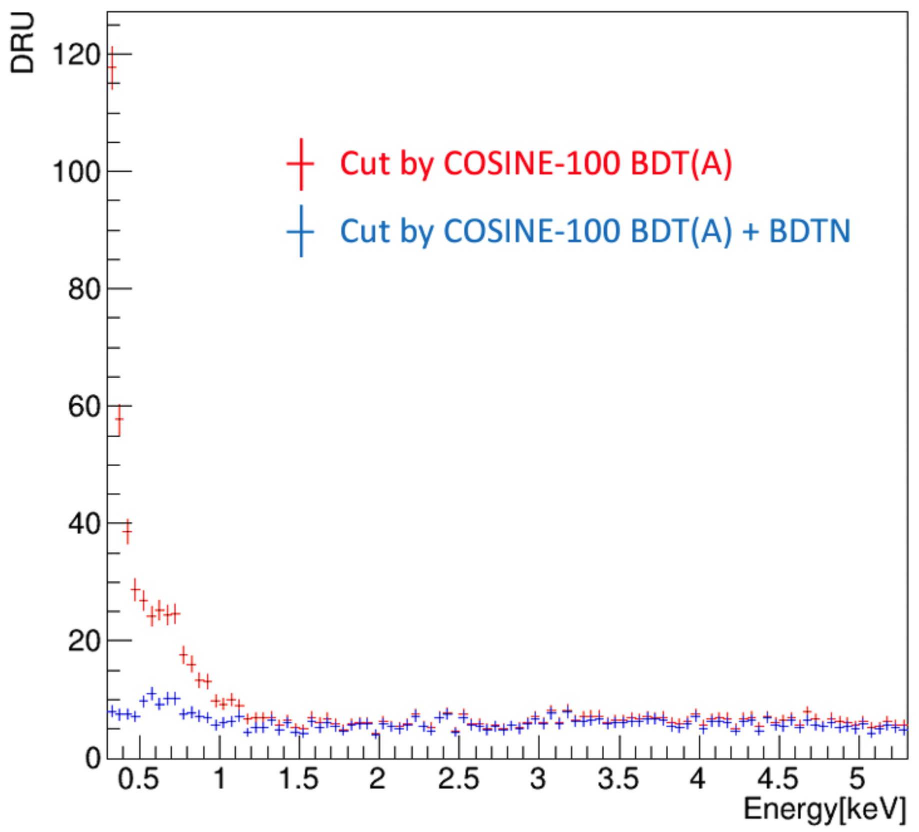
BDT training results



Applying previous (BDT,BDTA) and new bdt (BDTN) to NEON data

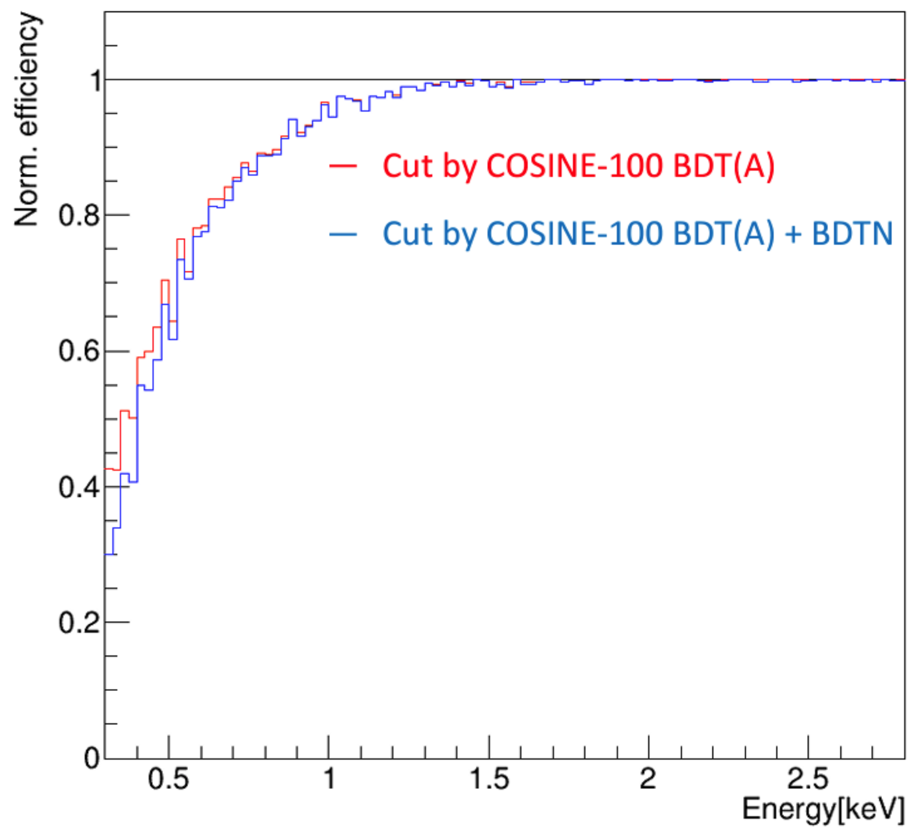


Energy Distribution



BDT & BDTA > -0.035
BDTN > -0.17

Efficiency



Simulation pre-cut by
same condition with bdt training cut

Summary

- Neutrino elastic scattering observation with NaI (NEON) is an experiment that aims to observe CEνNS using reactor antineutrinos.
- We have been collecting data since April 11, 2022. Currently, we have 399 days of reactor-on data and 144 days of reactor-off data.
- We are creating several variables, and it's an ongoing process.
- I've informally analyzed up to 0.3 keV using machine learning. Our next step involves exploring avenues to improve efficiency.

Plan

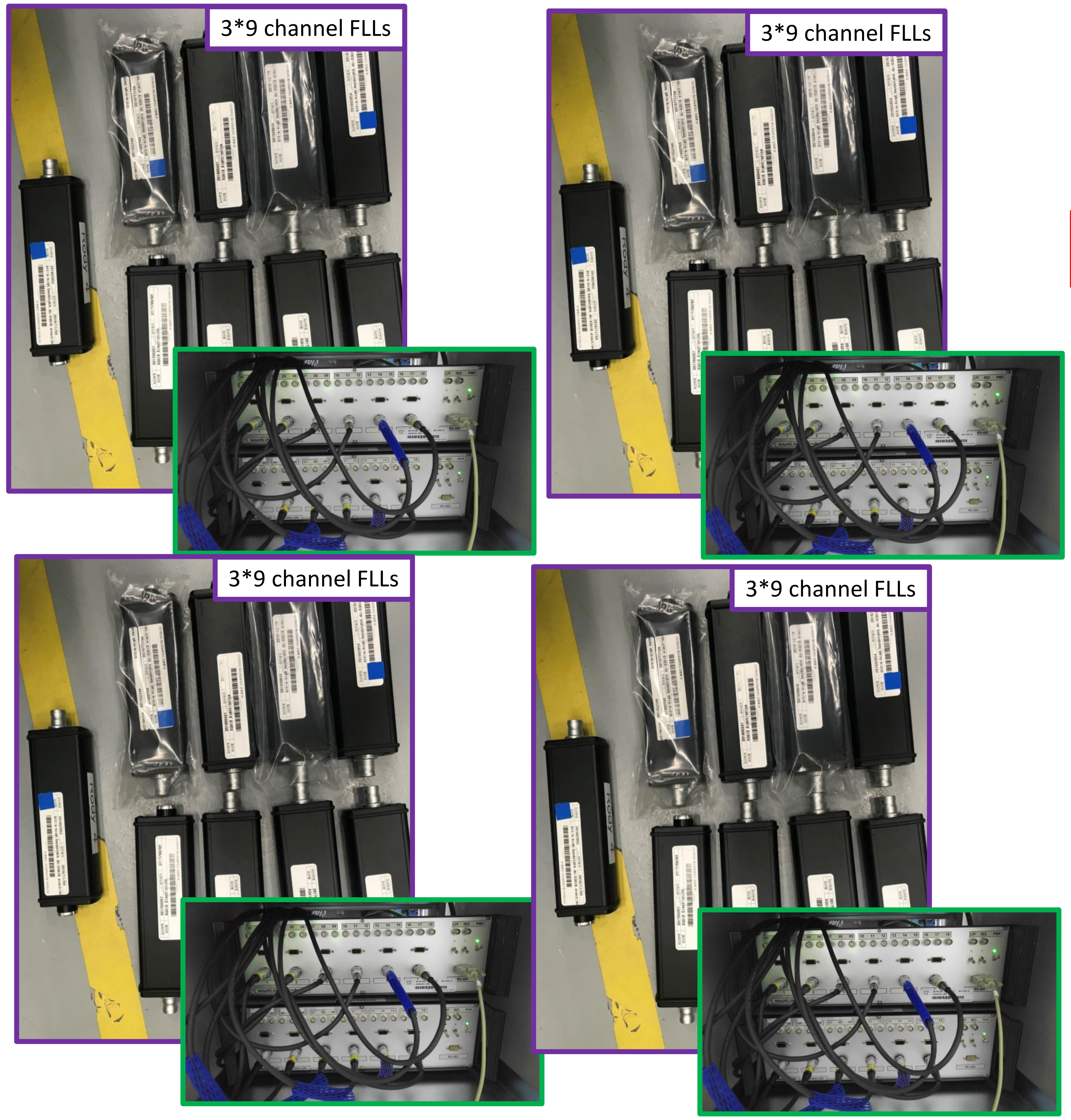
- We plan to update the monitoring code to enhance our understanding of the detector.
- We are developing variables using the Naive Bayes classifier as well as other variables, with plans to apply them to machine learning or deep learning in the future.

Researches in 2023

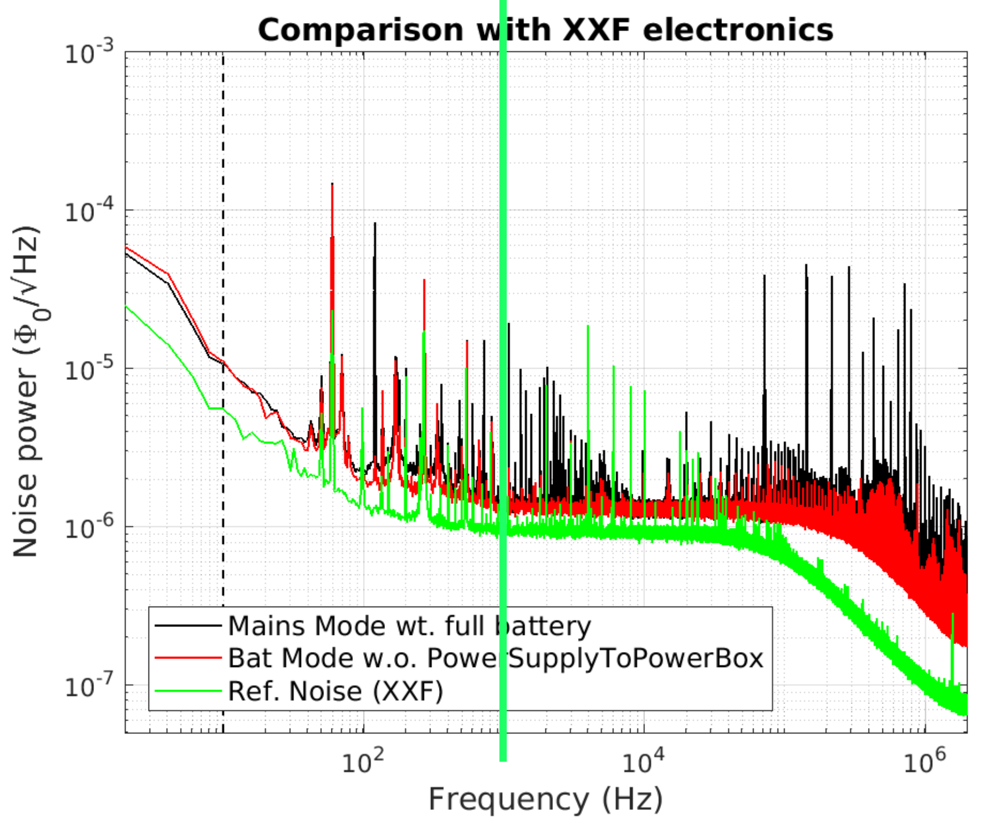
Jongseok Chung

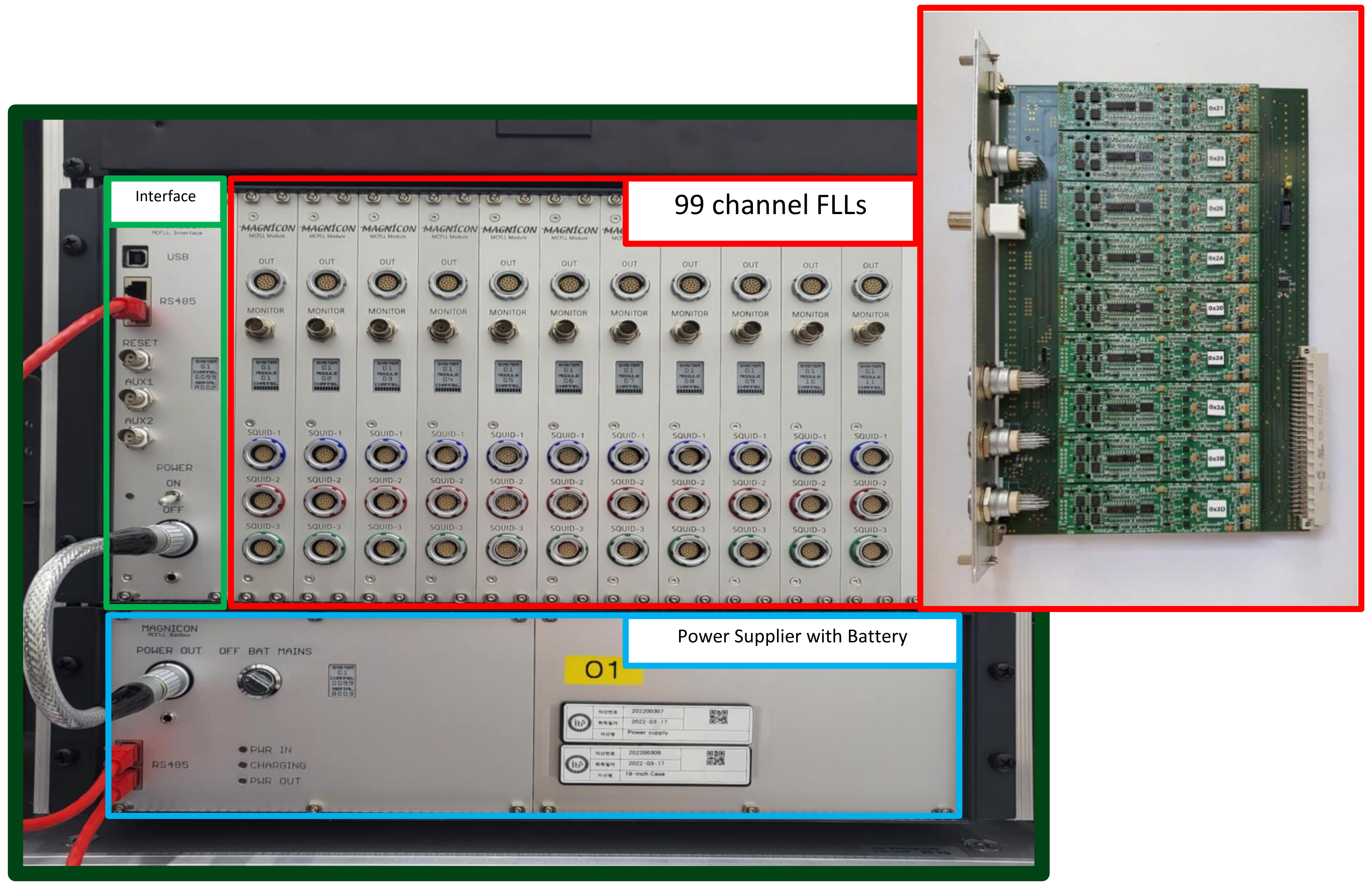
HEP Center 2023 Winter Workshop
2023.12.27 ~ 2023.12.28 | 곤지암 리조트

Development and testing the SQUID electronics



XXF-1
Operating 99 SQUID
(for AMoRE-pilot & I)





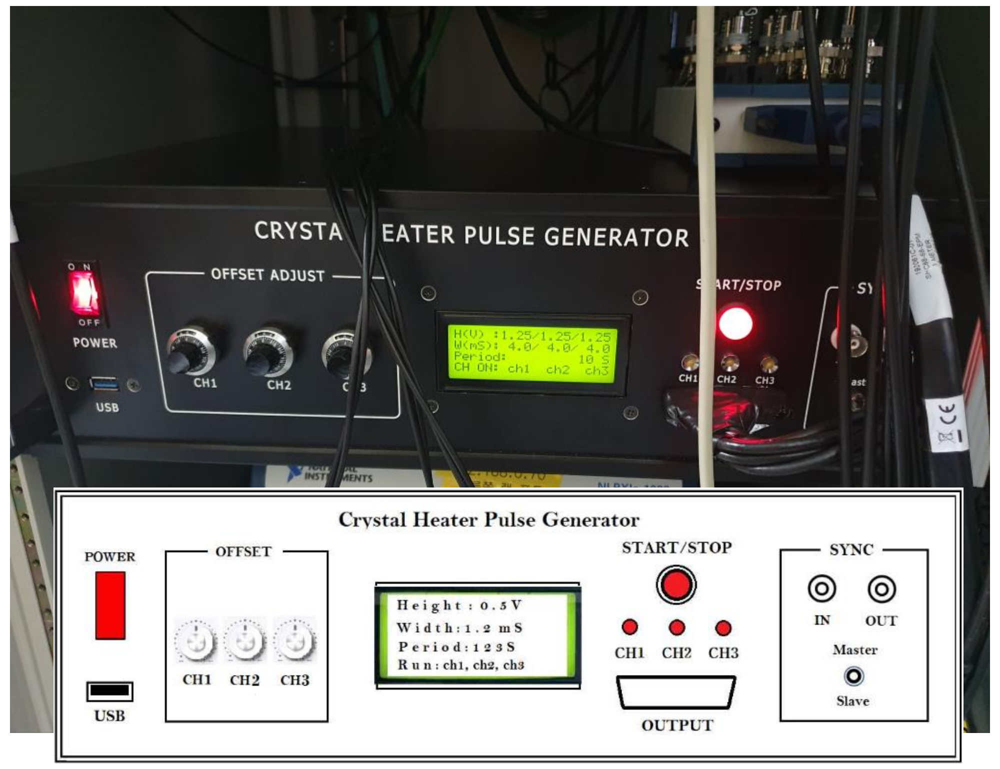
MCFLL[Multi Channel FLL]
Operating 99 SQUID
(for AMoRE-II)

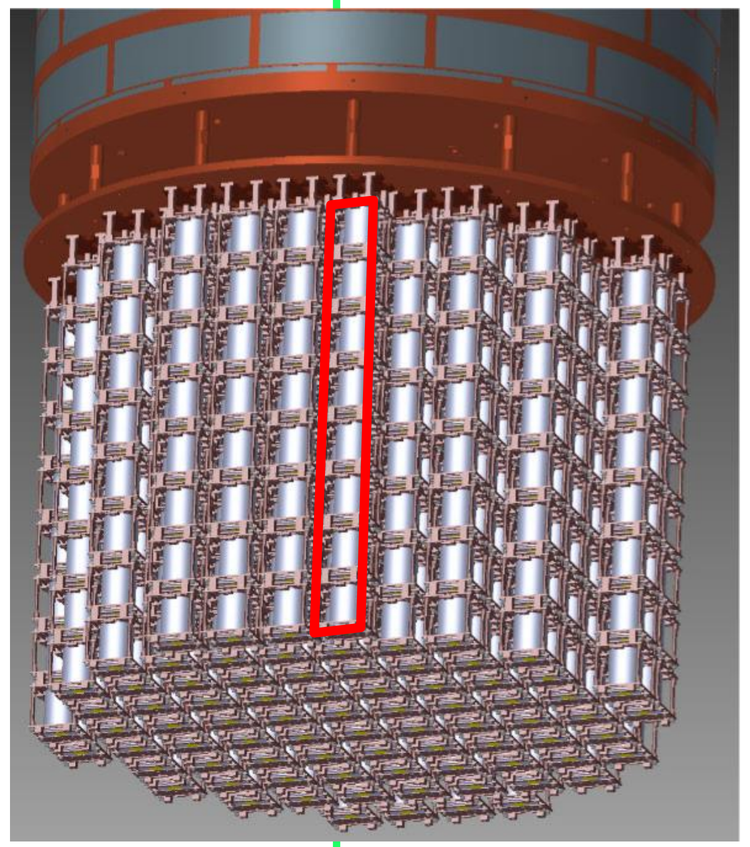
Development and testing the heater pulse generation electronics

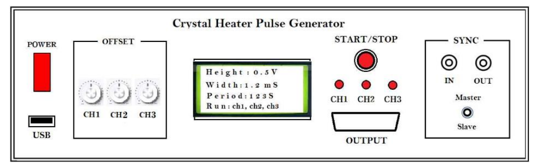
Previous one

For 12ch Pulse Generator

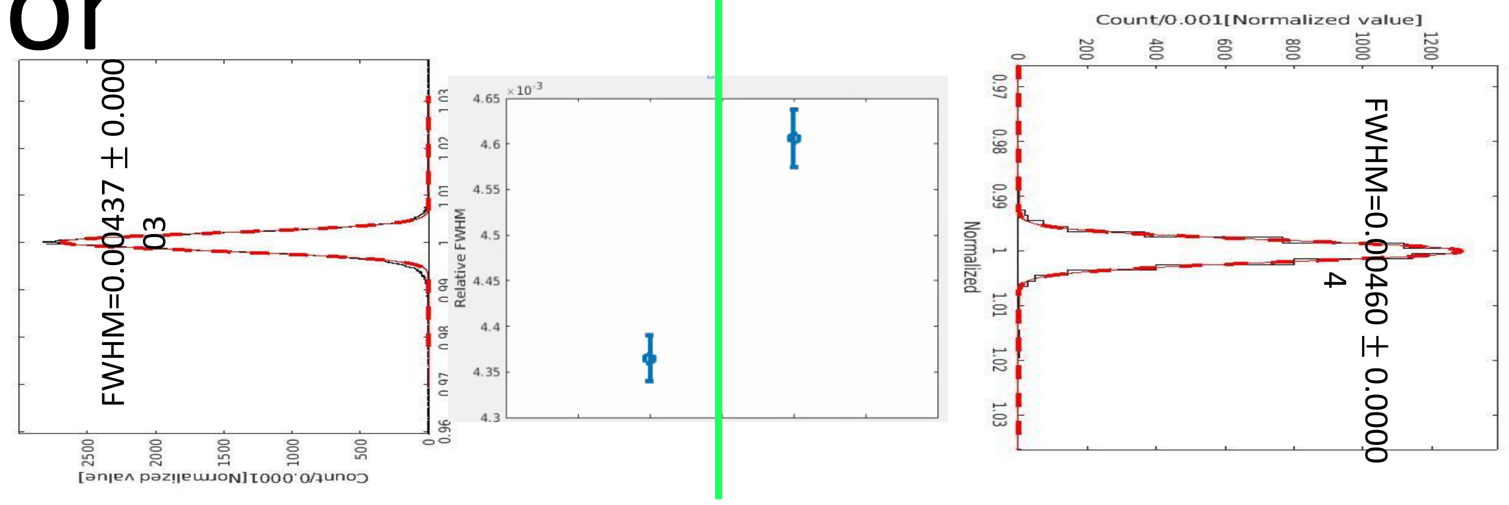
New one



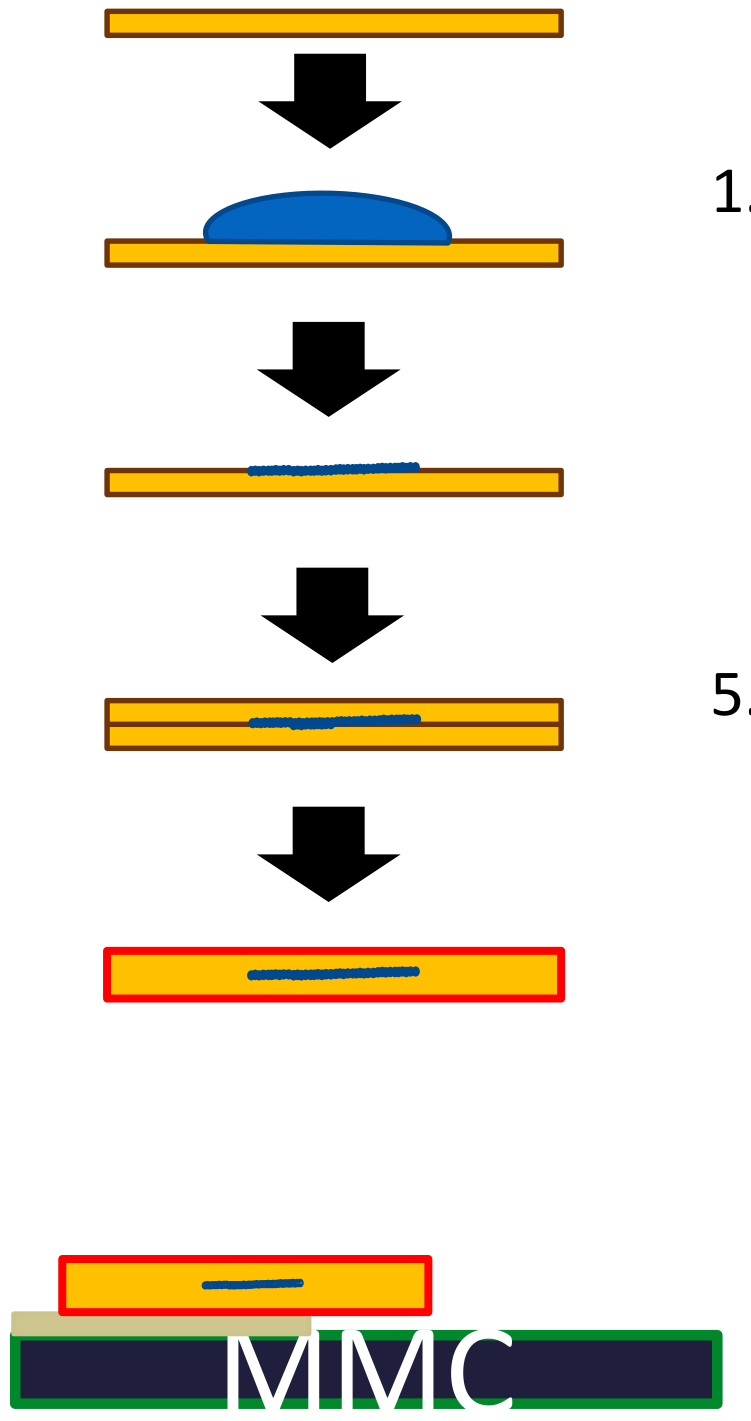




For 12ch Pulse Generator



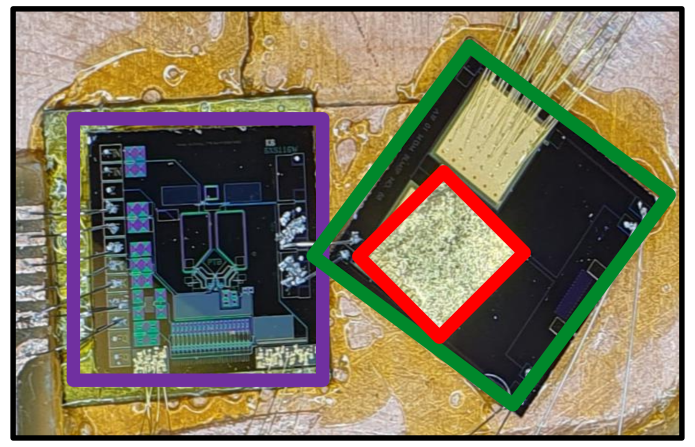
Development of Detectors for measuring radioactivity (^{226}Ra inside).

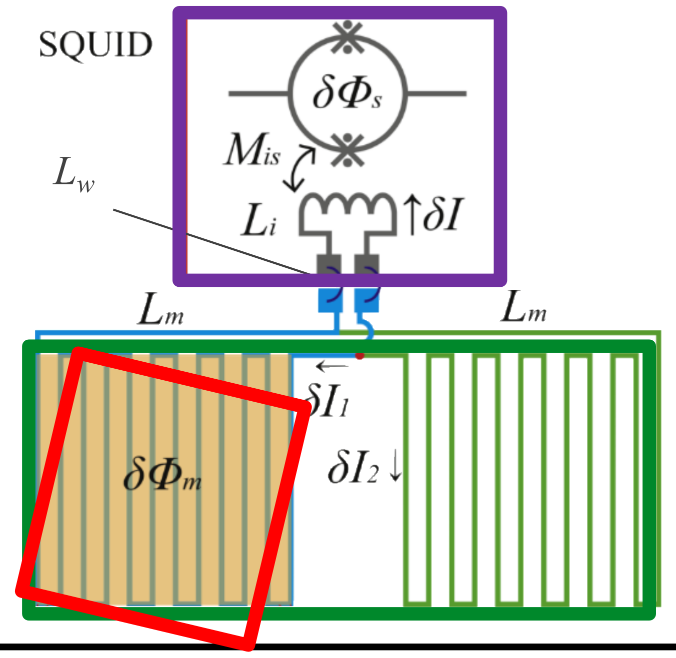


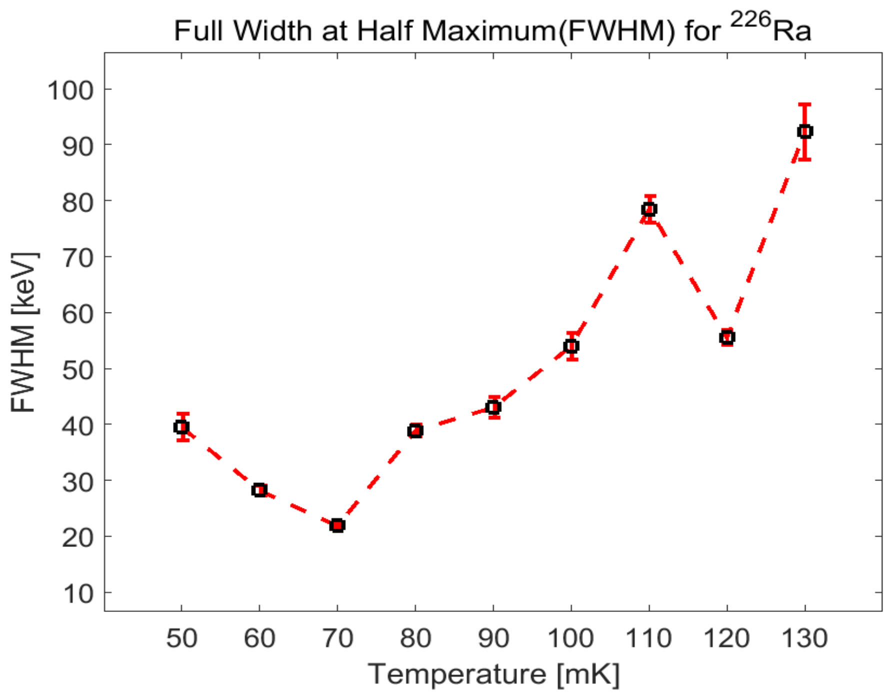
^{226}Ra DES Sample preraration

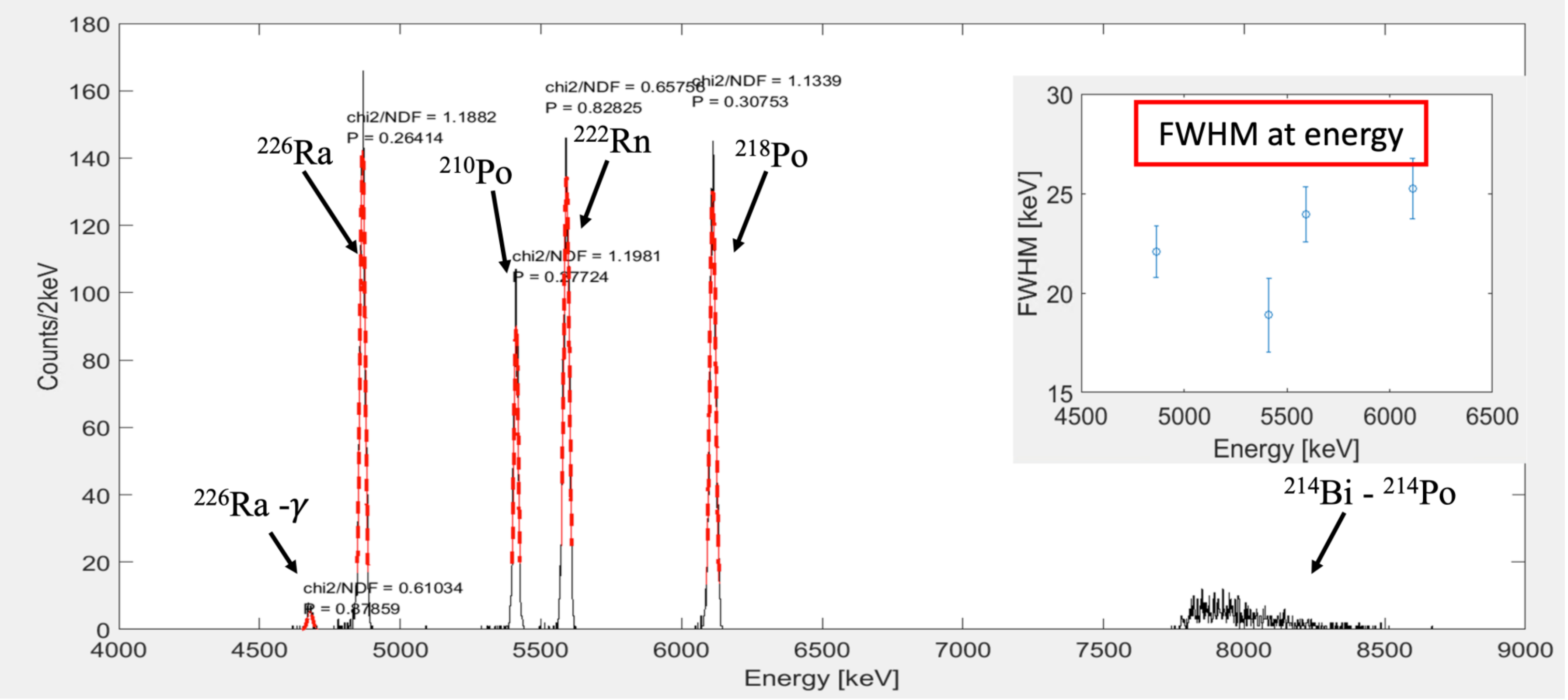
1. Prepare suitable size gold foil ($1.3 * 1.3 * 25$ [$mm * mm * \mu m$])
2. Drop the ^{226}Ra solution on the gold foil (about 1Bq → 0.2 μL of solution)
3. Heat the gold foil for small salt of ^{226}Ra (about 70℃)
4. Embedding by laying another foil
5. Place weight on sandwiched foil and heat for the diffusion welding (600℃, 3 h)

$$\delta\Phi_s = M_{is}\delta I = \frac{M_{is}}{L_m + 2(L_i + L_w)}\delta\Phi_m$$









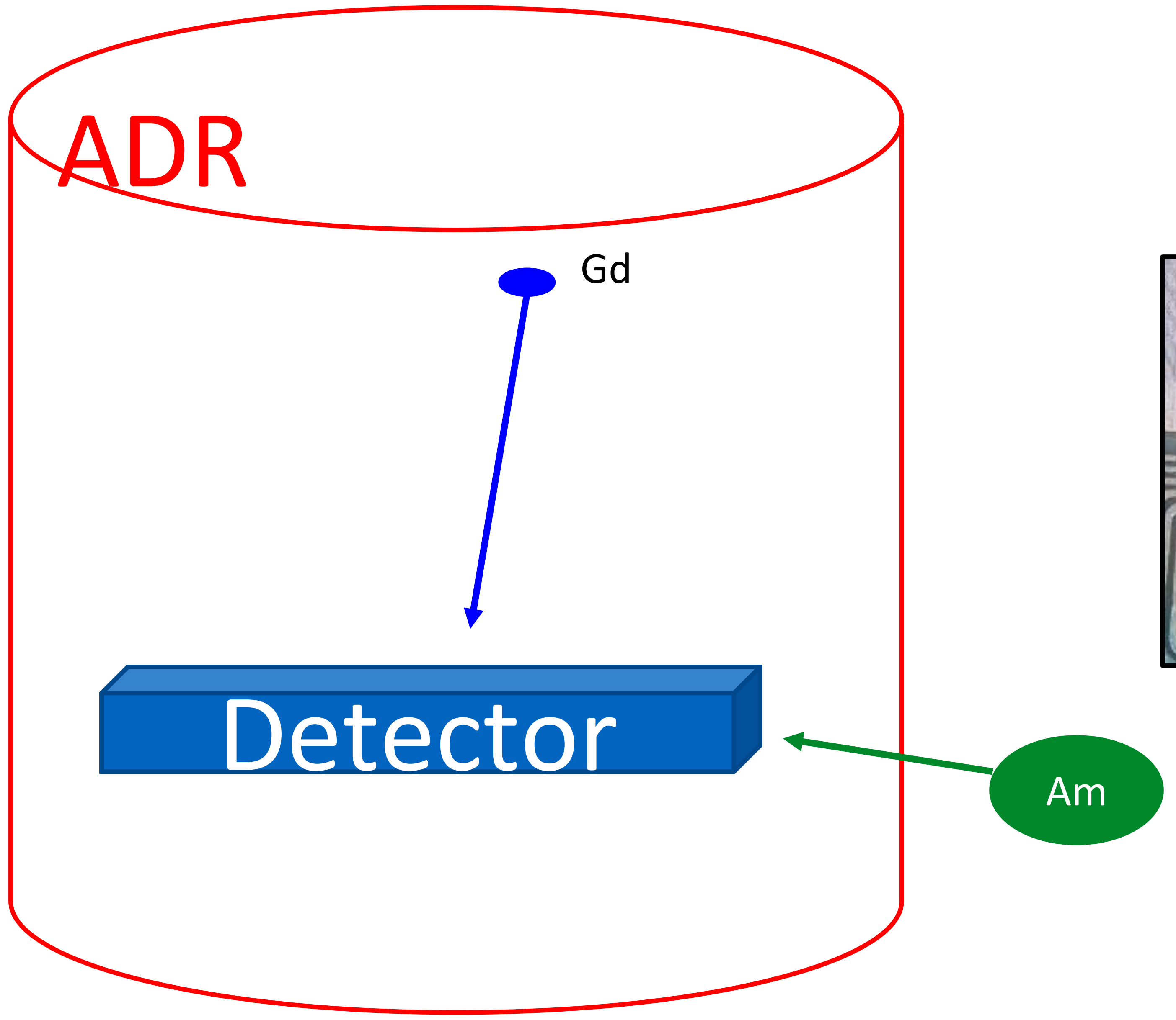
- The well-defined energies correspond to the following transitions with their respective Q-values: 4871 keV, 5590 keV, and 6115 keV for $^{226}Ra \rightarrow {}^{222}Rn \rightarrow {}^{218}Po \rightarrow {}^{214}Pb$, as well as 5407 keV for $^{210}Po \rightarrow {}^{206}Pb$.
- The energy resolutions are 22 keV, 18 keV, 23 keV, and 25 keV at 4871 keV, 5407 keV, 5590 keV, and 6115 keV.
- The discrimination power of nearest two peaks are 14.7 calculated by $DP = \frac{\mu_2 - \mu_1}{\sqrt{\sigma_2{}^2 - \sigma_1{}^2}}$.

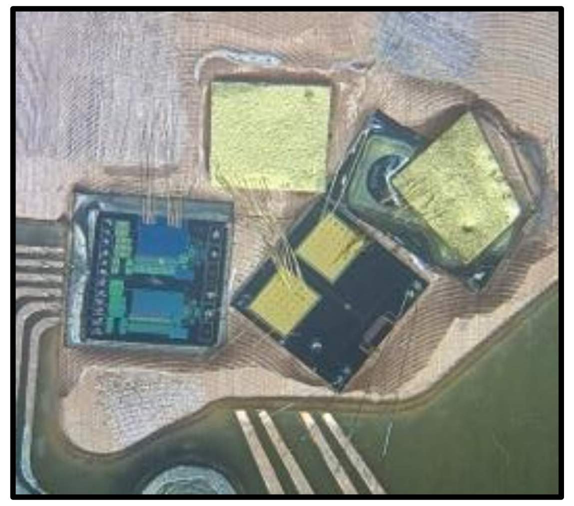
Development of Detectors for measuring radioactivity (only Au).

We have two kinds of data set :

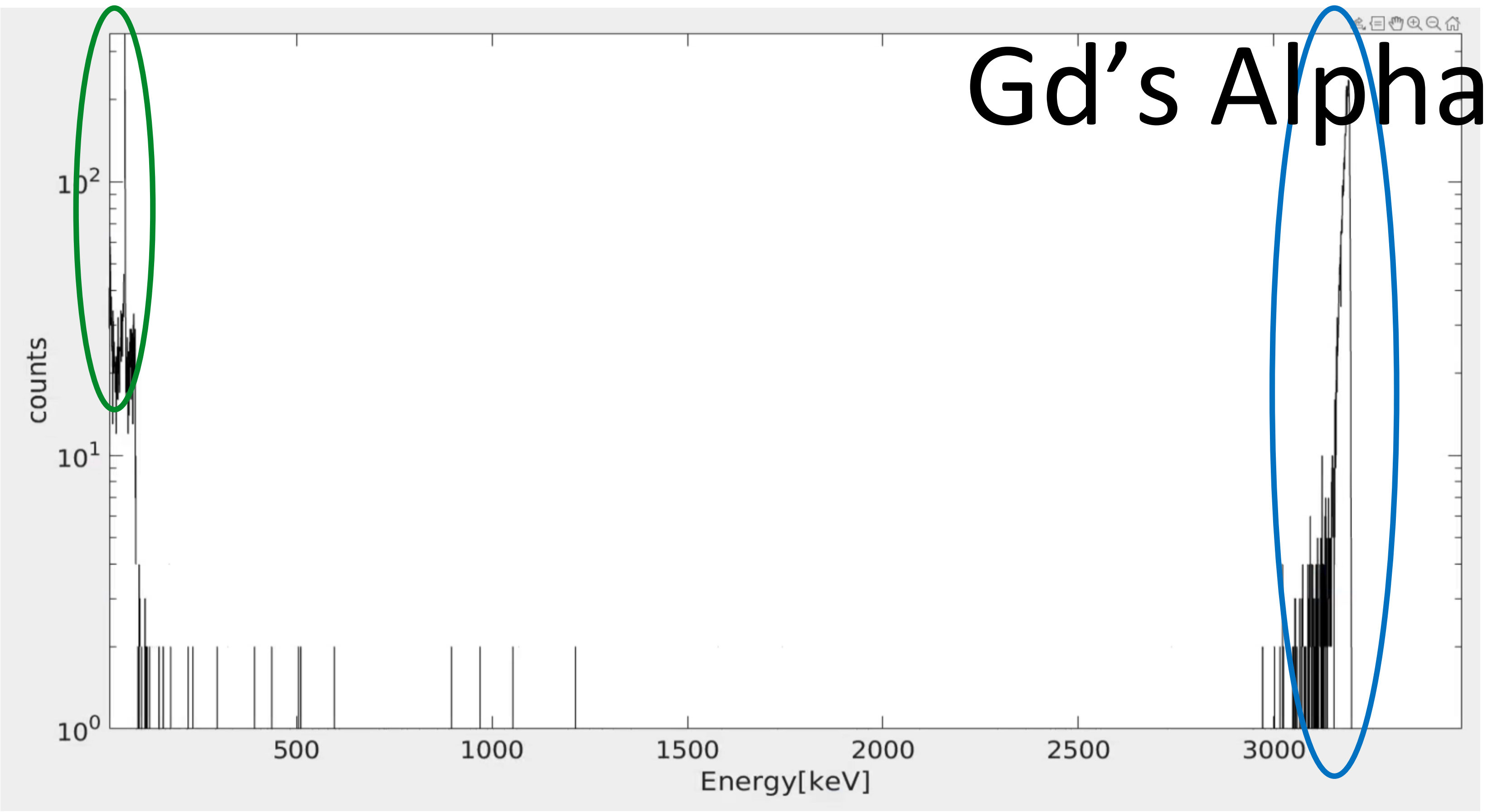
1. With ^{241}Am's gamma (59.5[keV](35.9%)) and ^{148}Gd's alpha (3186[keV]) source [~4h]
   (for comparing **positive sig** and **negative sig**)

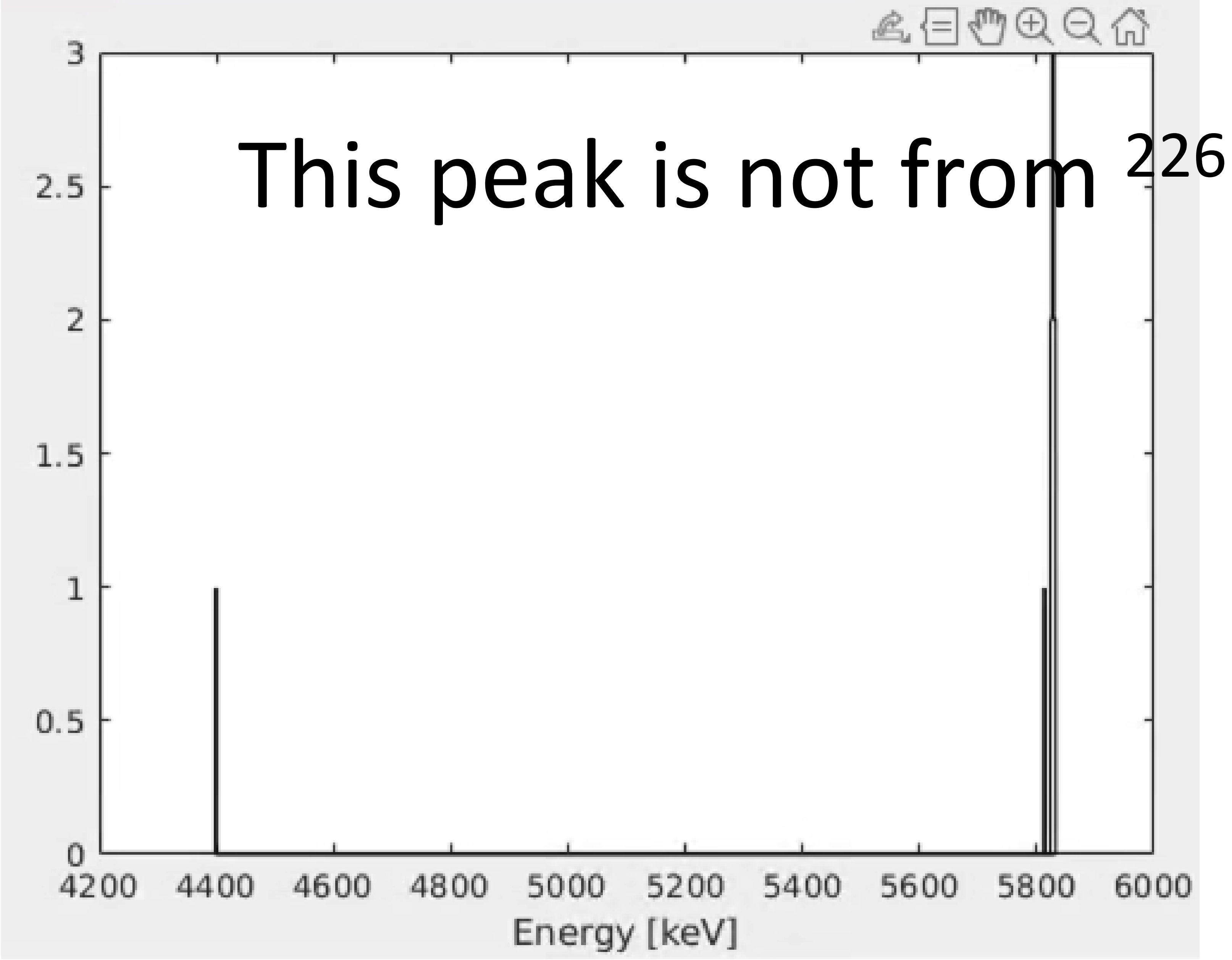
2. Only Gd source (without Am) [~24h]
   (for callibrating our region of interest [5-7 MeV])





Am's Gamma peak





Summary

- **The electronics that we will use in AMoRE-II are tested.**

- **Radioactivity detectors are been developing well.**
  Considering the results so far, it is possible to measure up to 50 [uBq].
  Stay tuned!

Researches in 2023

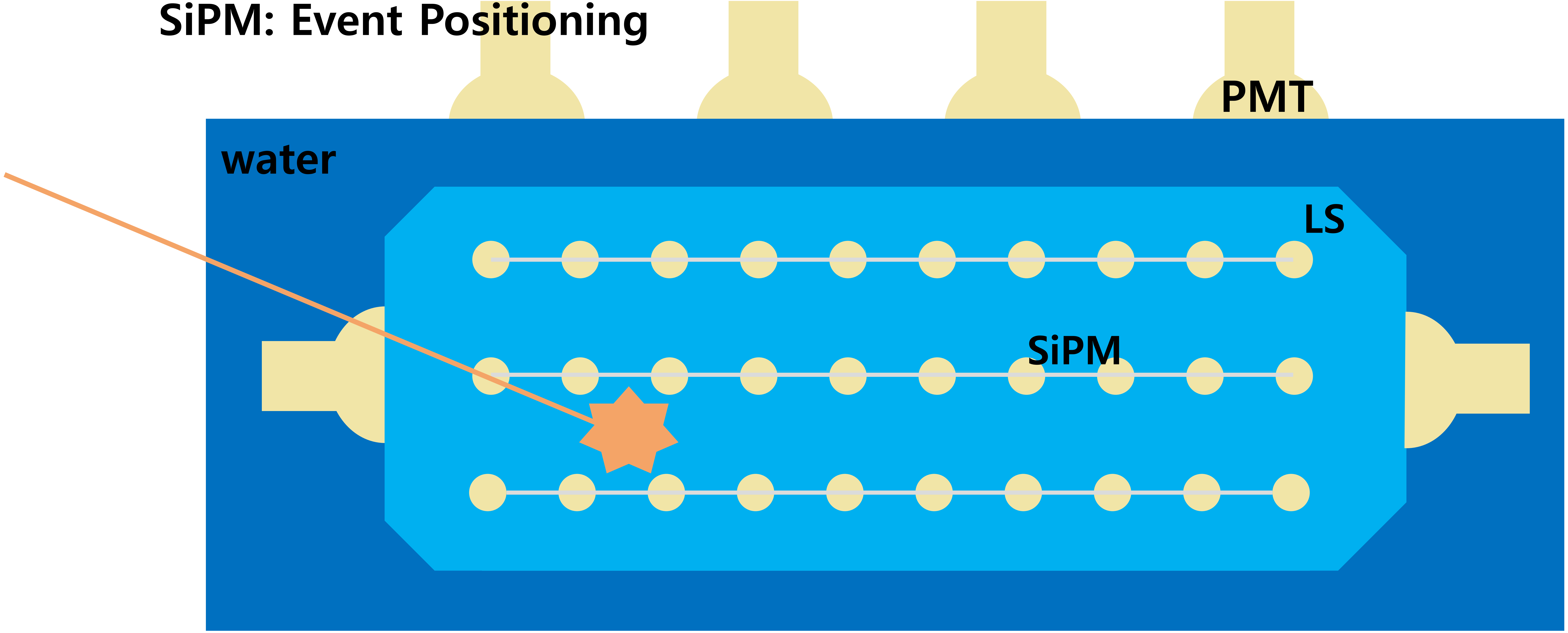
Hani Kimku

HEP Center 2023 Winter Workshop
2023.12.27 ~ 2023.12.28 | 곤지암 리조트

Mini-Candy

Candy : Chung-Ang university Neutrino Detection Yolk

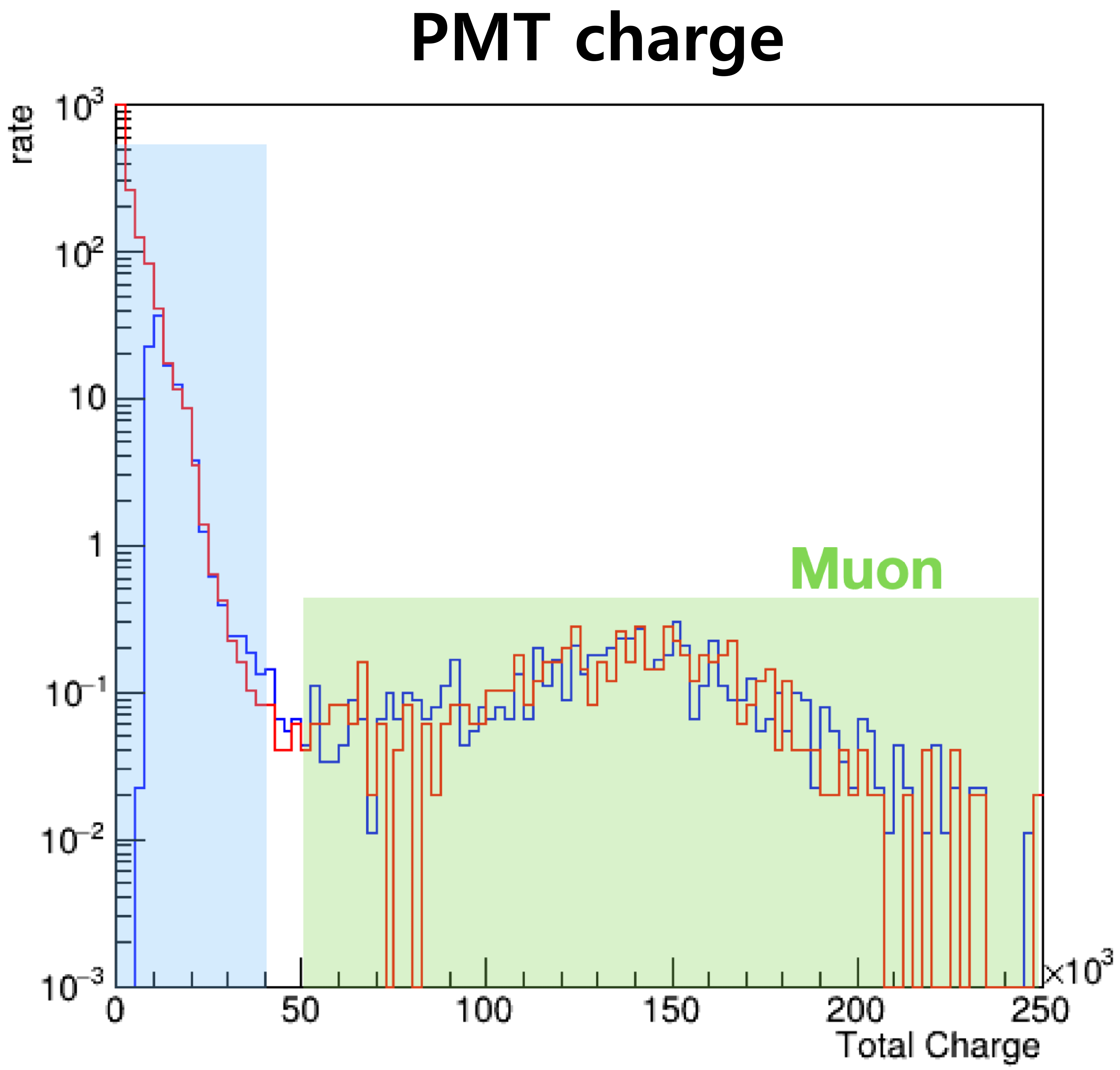
Water: Muon veto & background noise shielding
PMT : Event Energy reconstruction
SiPM: Event Positioning

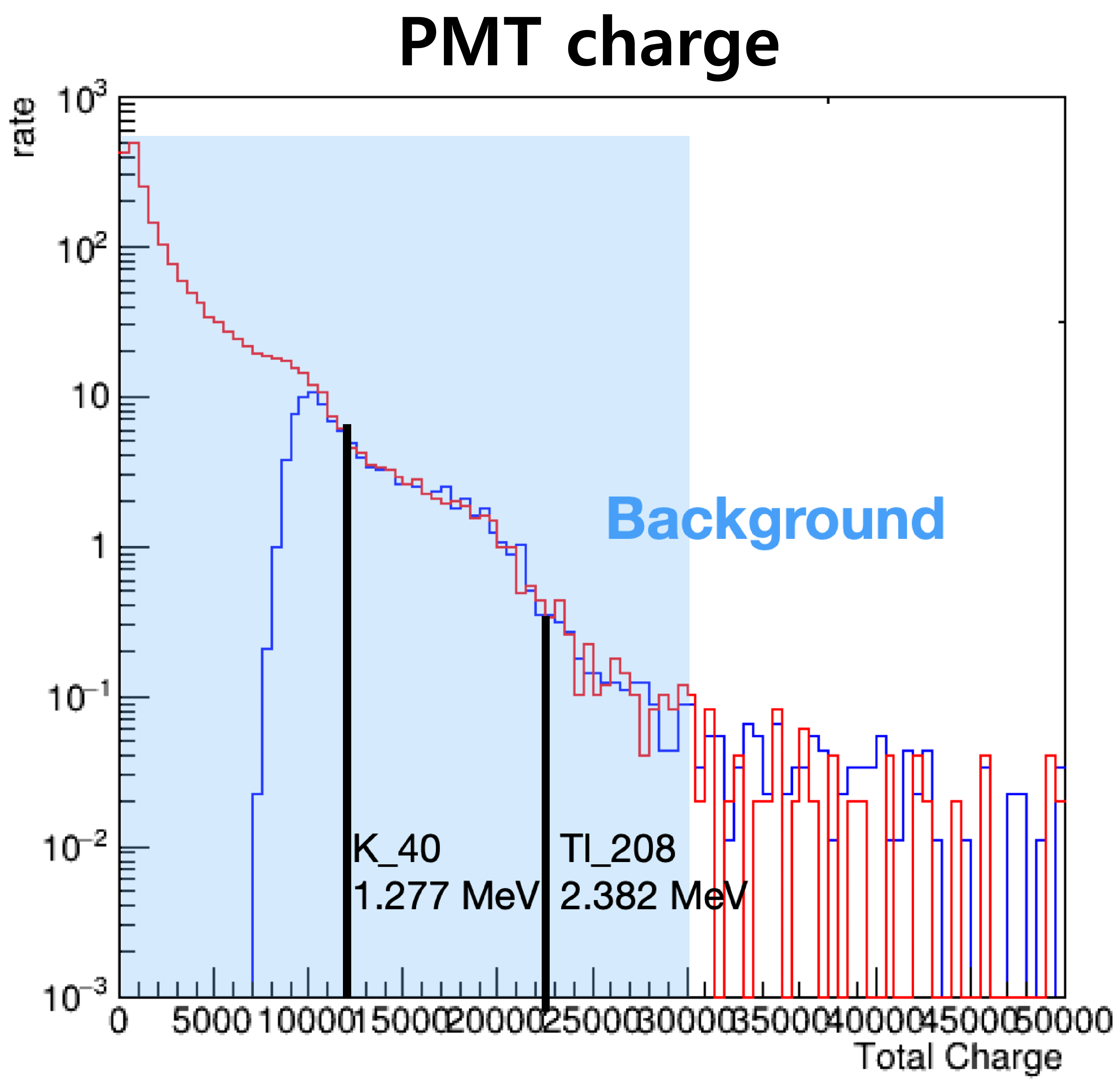


Mini-Candy

Mini-Candy

LS Scintillation

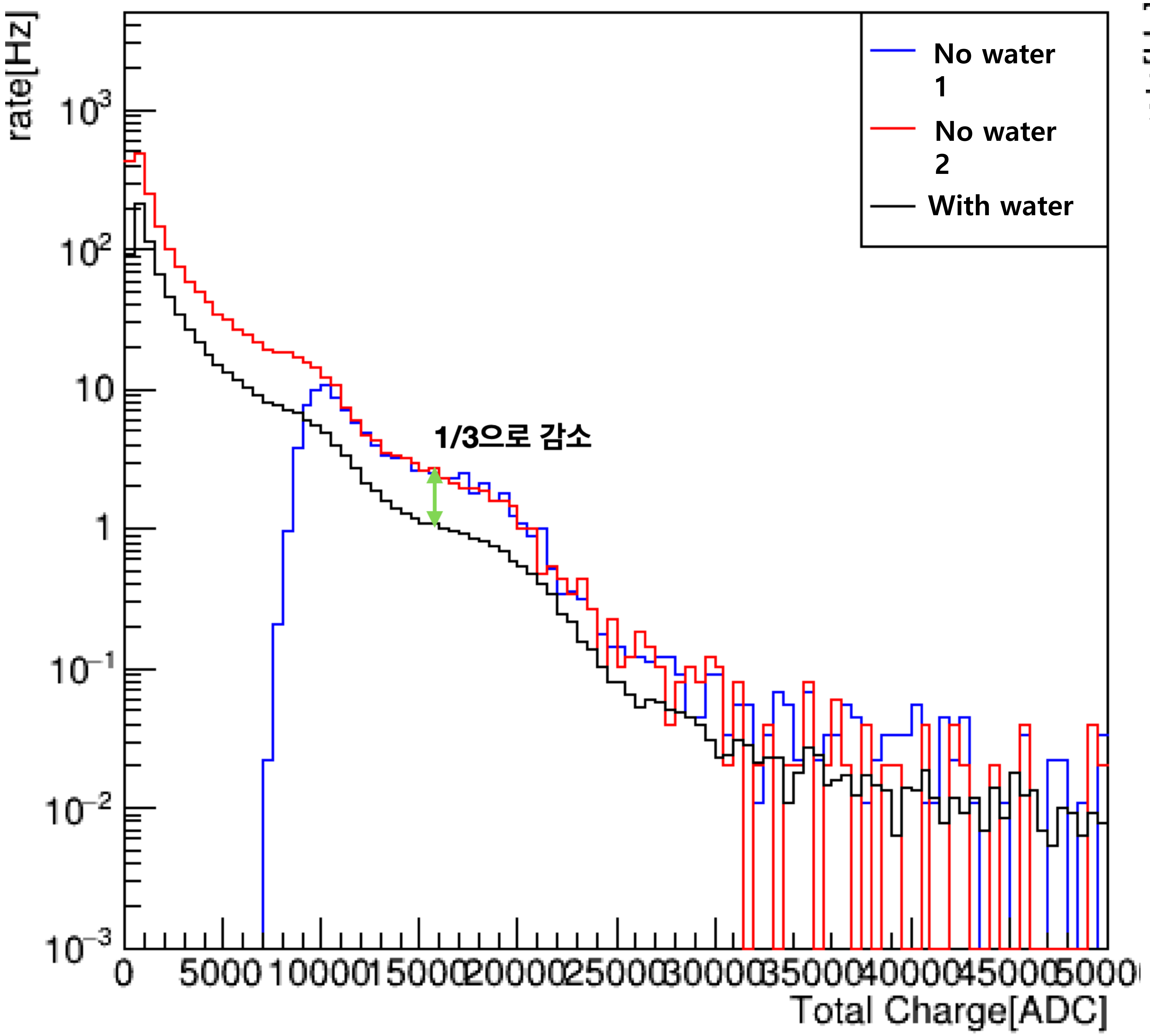


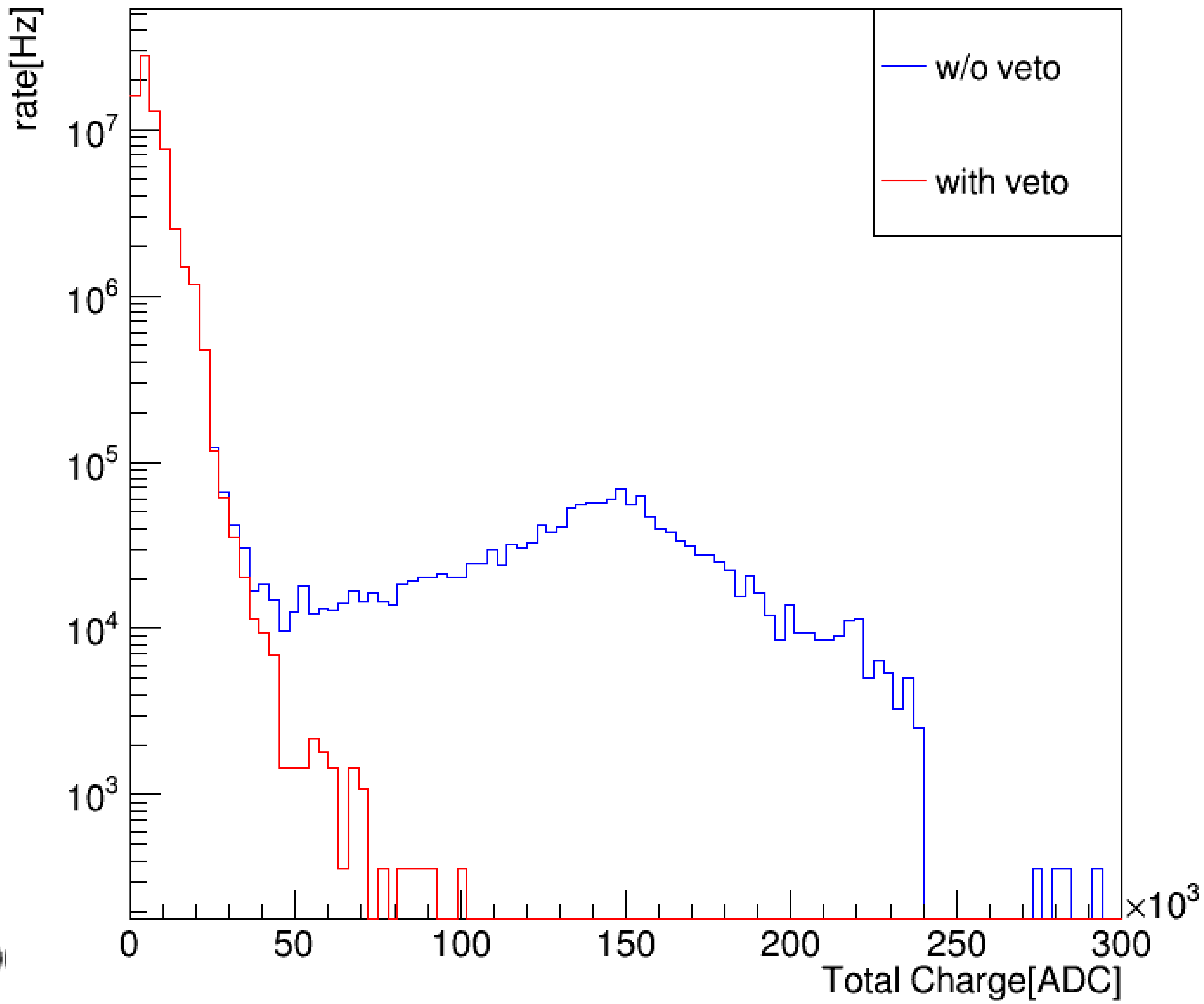


Muon rate : About 120 Hz / m^2

Mini-Candy

Water effect





Summary

MC is a multi-detector using PMT, SiPM, water, and LS

- **Checked water Cherenkov light**
- **Checked water shielding effect**
- **Checked water veto effect**

Plan

- **SiPM will be installed inside the detector**
- **We will do event positioning through SiPM**

Researches in 2023

Seong Joon Won

HEP Center 2023 Winter Workshop
2023.12.27 ~ 2023.12.28 | 곤지암 리조트

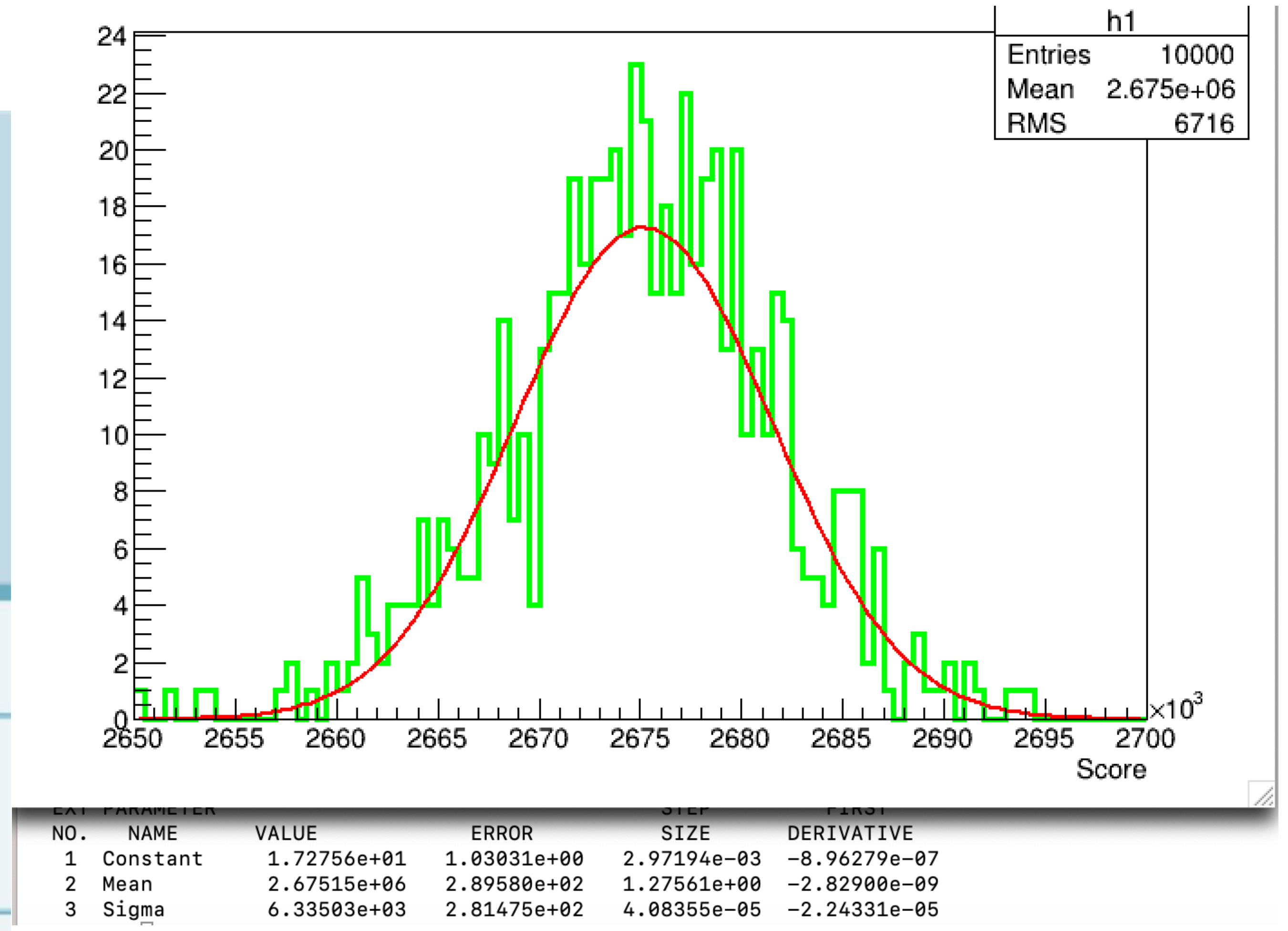
HPGe Detector Resolution calculate

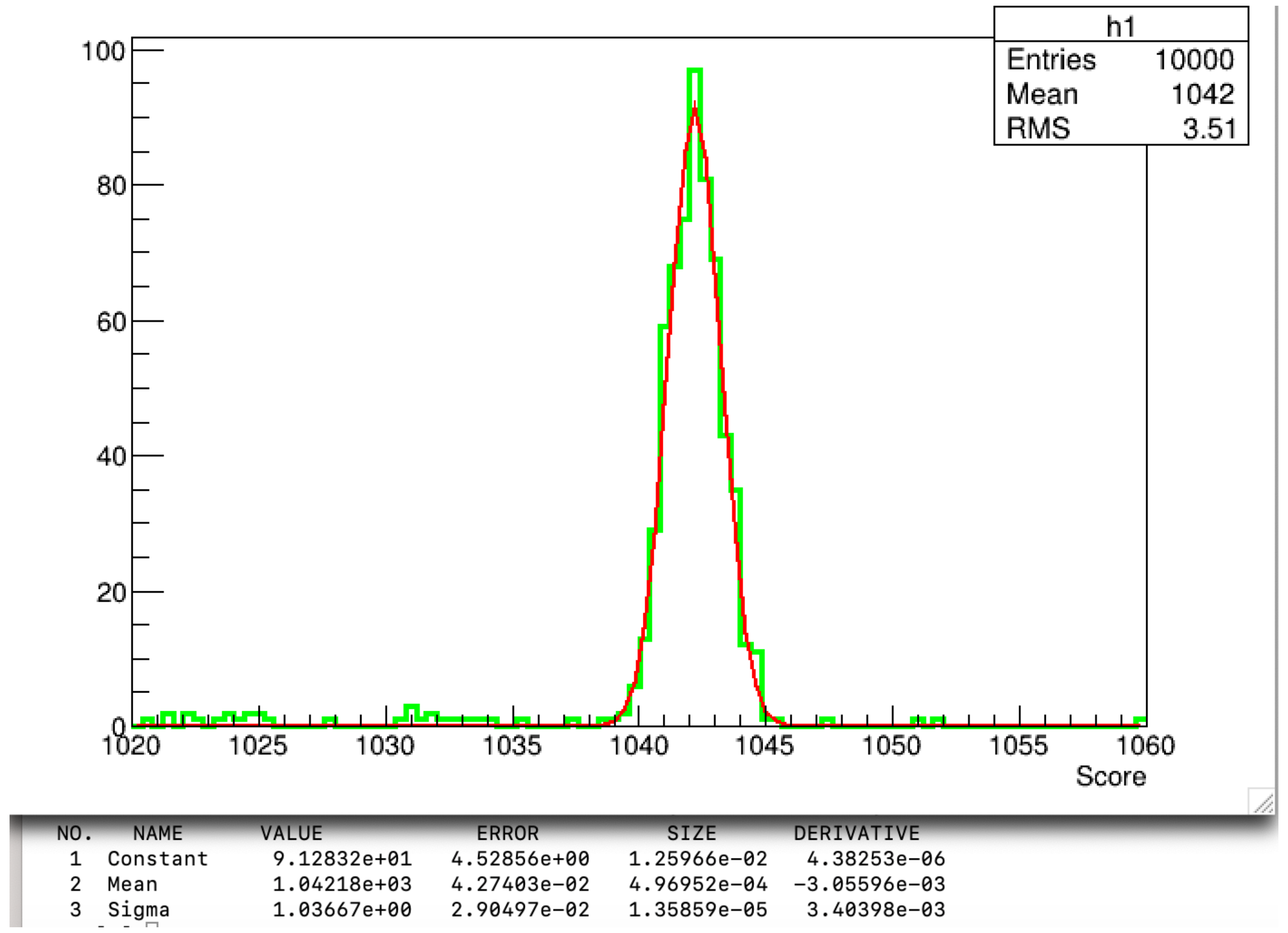
Left) HPGe Detector with Dewer
Up) Yellow signal – signal before passing through amplifier
Green signal – signal after passing through amplifier

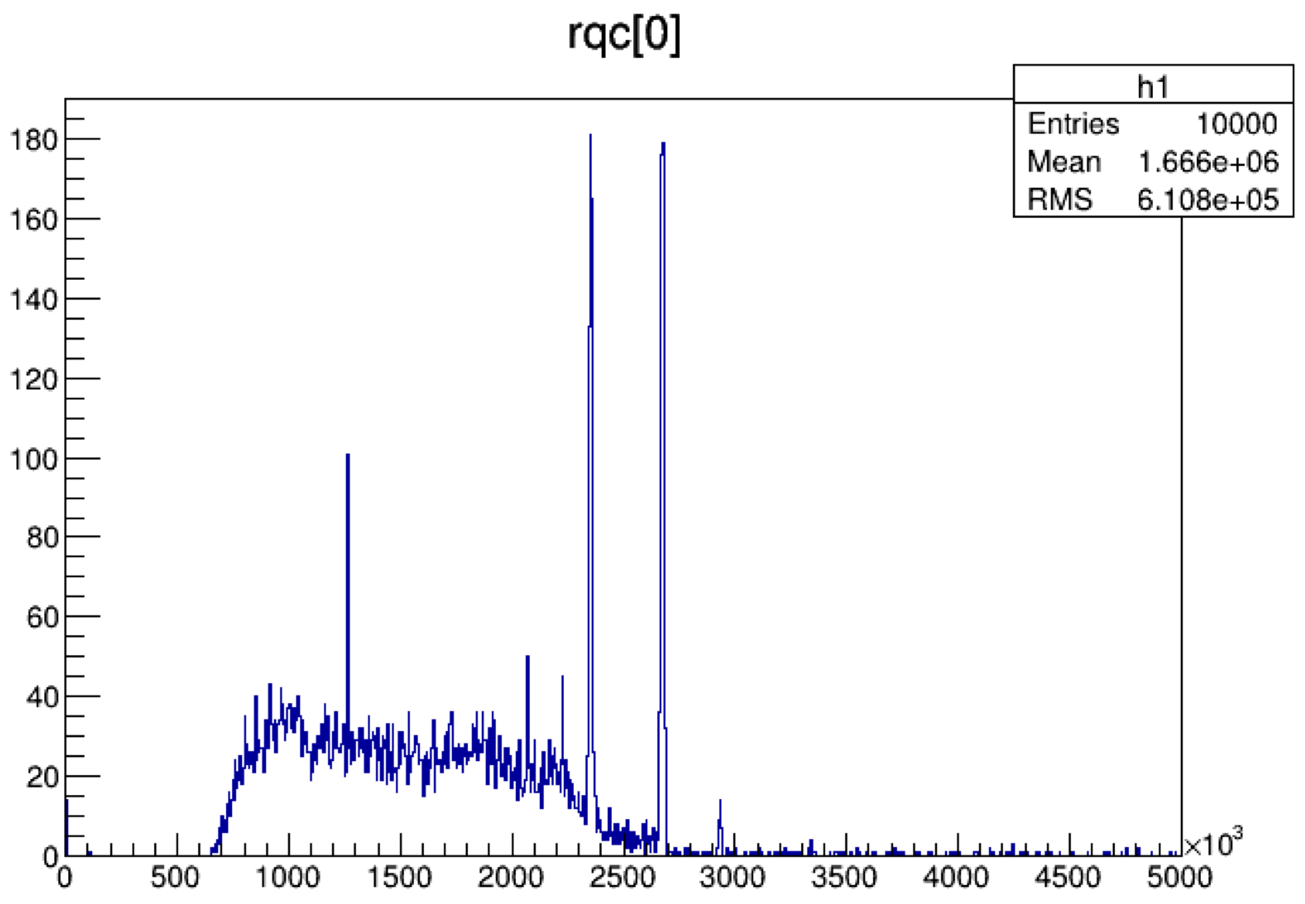
HPGe Detector Resolution calculate

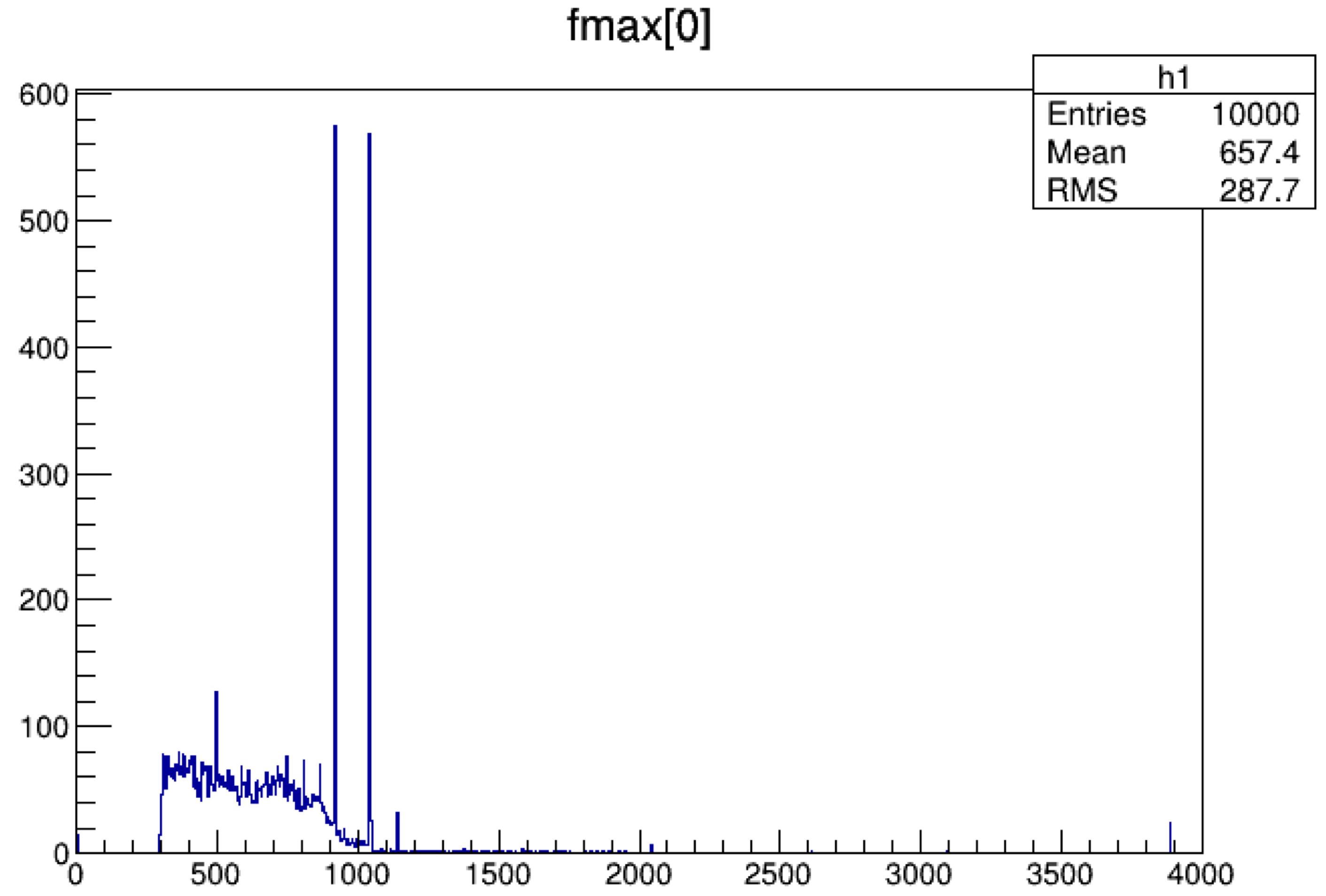
Model Number	Relative Efficiency (%) ≥	Full Width Half Max (FWHM) Resolution (keV)		Peak to Compton Ratio (P/C)	Peak Shape	Endcap diameter mm (in.)
		At 122 keV energy	At 1.3 MeV energy		FWTM/ FWHM	
GC0518	5	0.825	1.8	32	1.90	76 (3.0)
GC1018 GC1020	10 10	0.825 1.0	1.8 2.0	38 34	1.90 2.00	76 (3.0) 76 (3.0)
GC1518 GC1520	15 15	0.825 1.0	1.8 2.0	44 40	1.90 2.00	76 (3.0) 76 (3.0)
GC2018	20	0.850	1.8	50	1.90	76 (3.0)
GC2020	20	1.10	2.0	46	2.00	76 (3.0)

Resolution calculate with FWHM = 0.000588







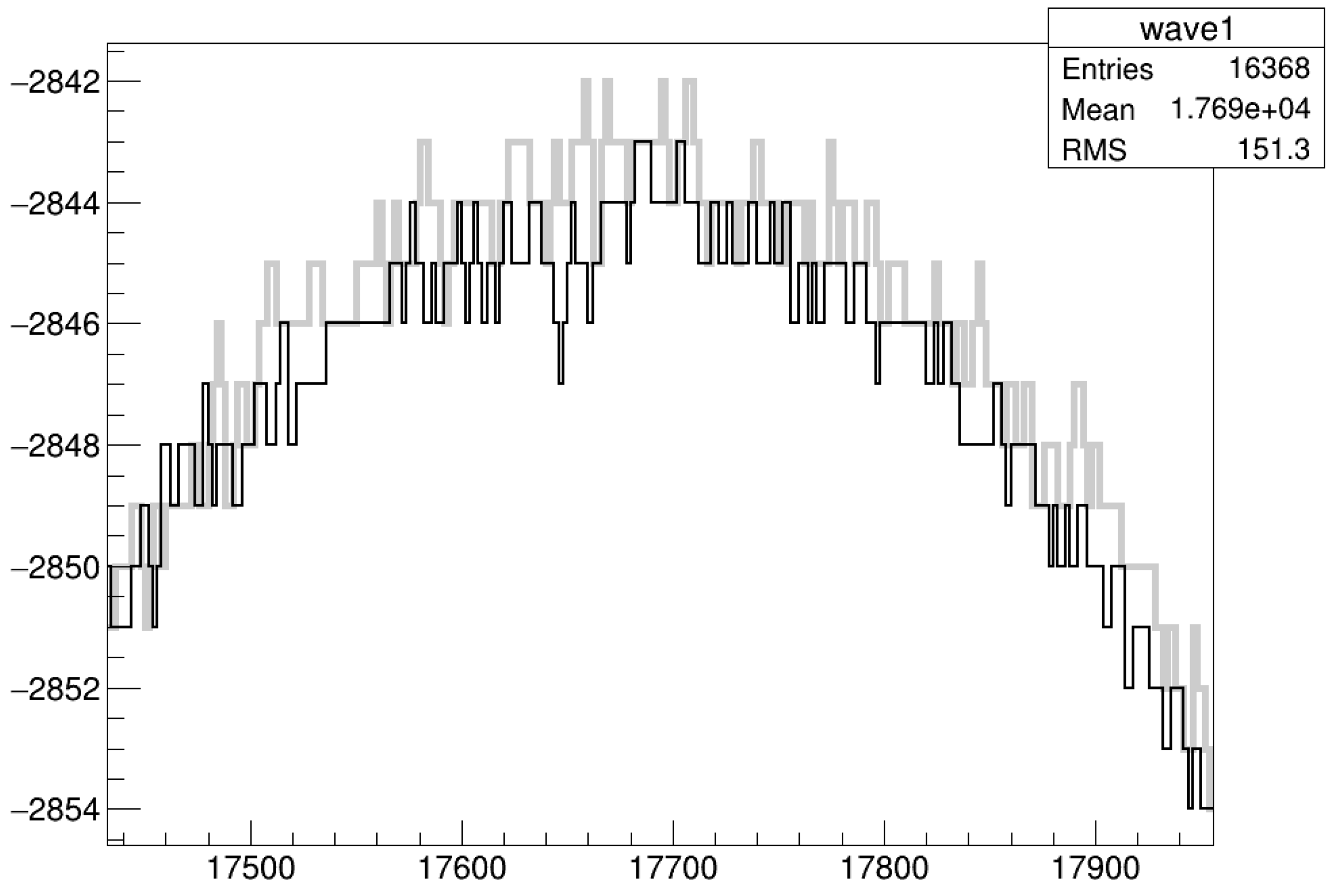


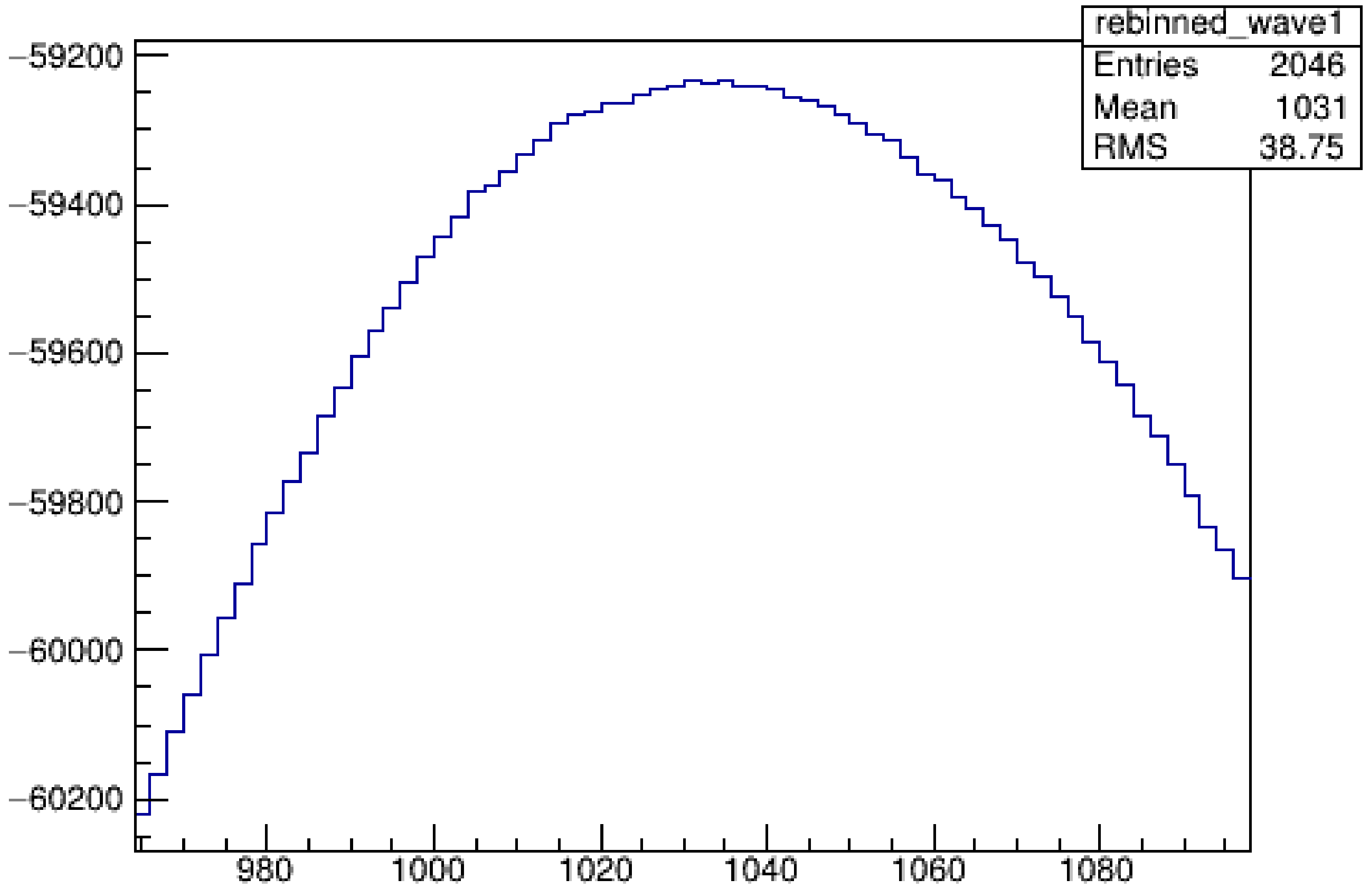
Resolution = 0.00237

Resolution = 0.00098

HPGe Detector Resolution calculate

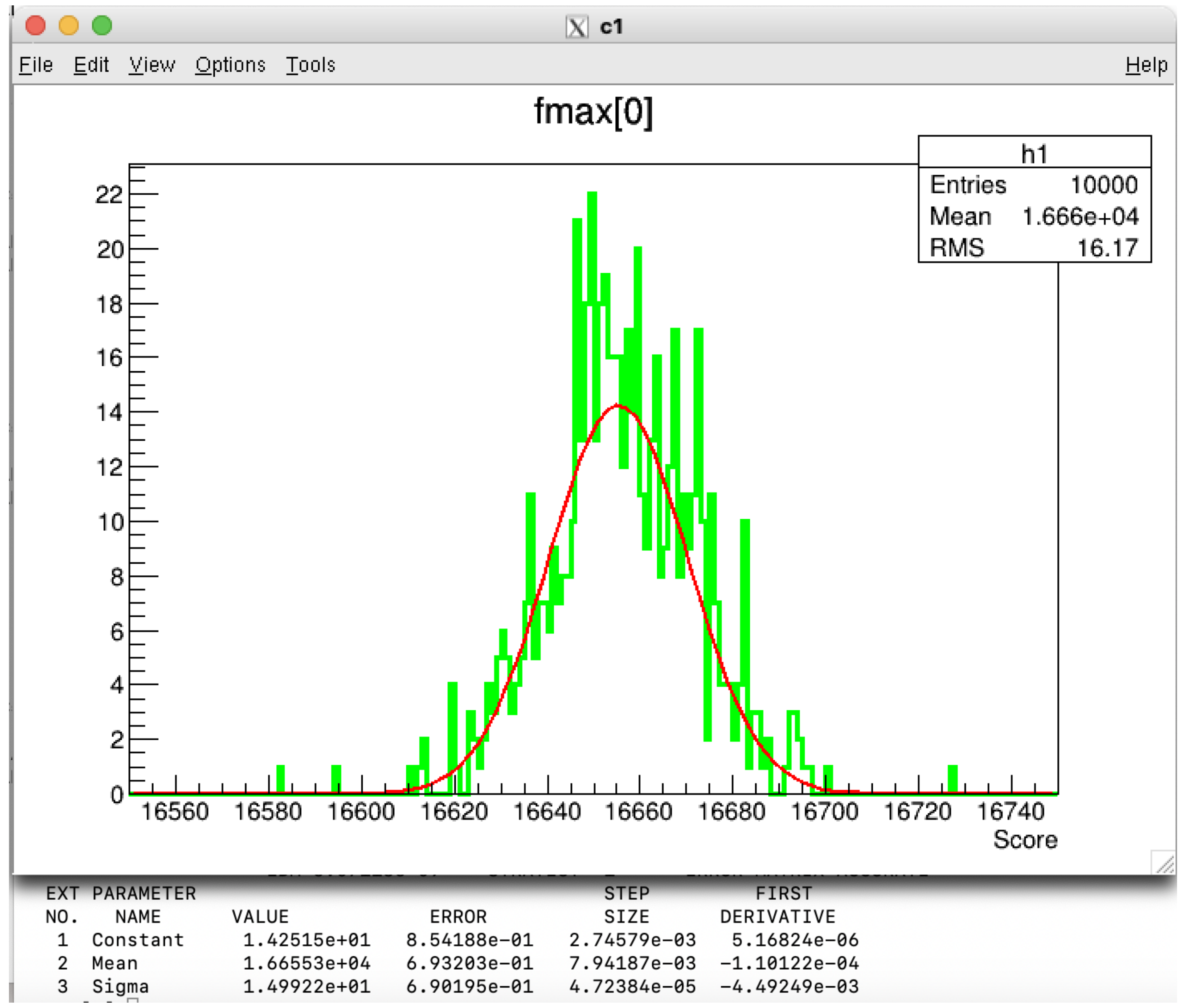
Fmax calculate after Rebin : Fluctuation in fmax is reduced



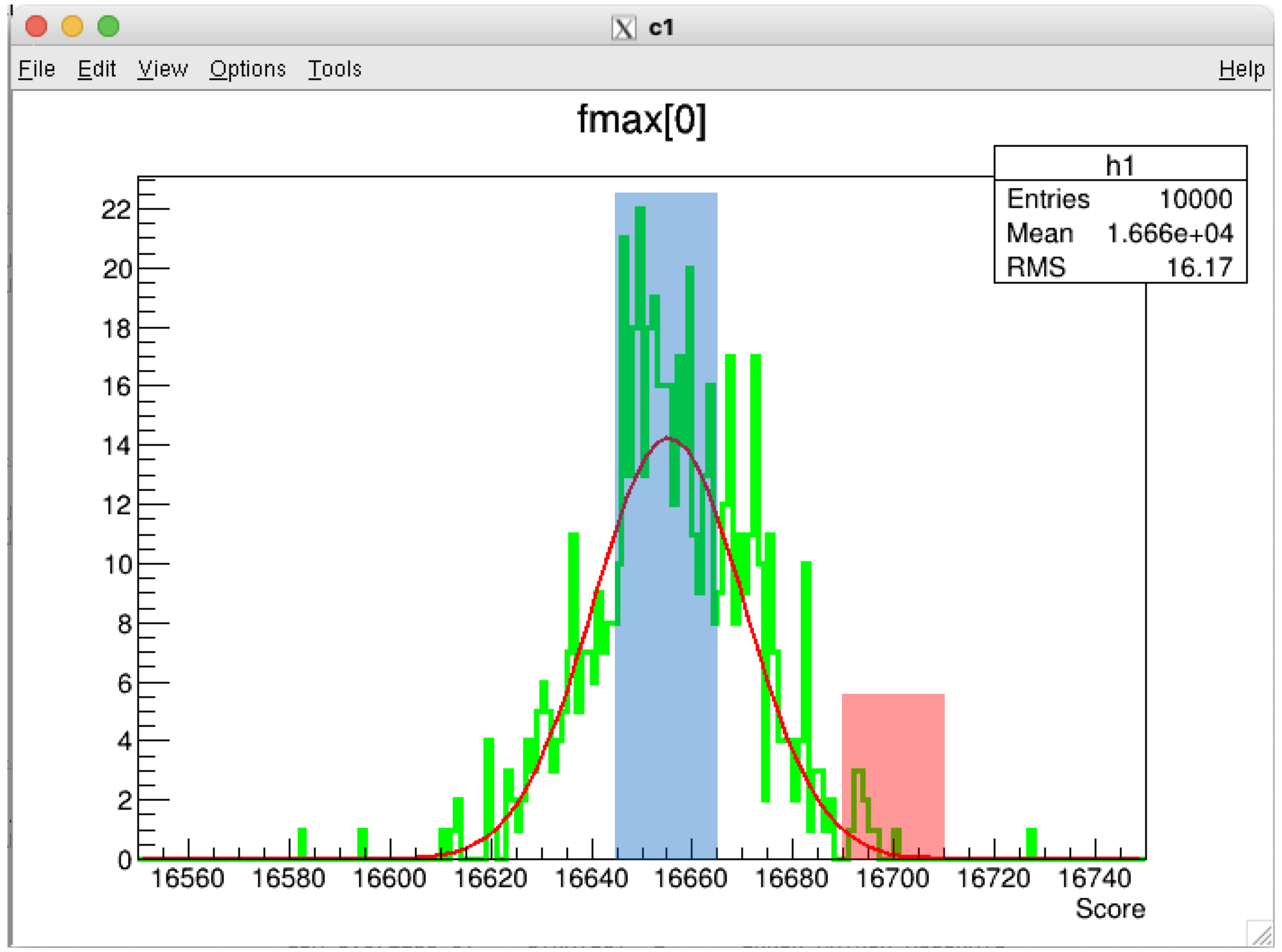


Resolution calculate after Rebin : Resolution is improved

	rqc[0]	fmax[0]	fmax[0] Rebin
Resolution	0.00237	0.00098	0.0009



HPGe Detector Resolution calculate



Difference between fmax value and pedestal value after Rebin

- Events near the 1.3MeV peak(Blue) and away from the peak(Red) were compared
- There is a significant difference in fmax values other than pedestal
- The difference in fmax can be seen as a problem with the value itself measured by the machine, so it can be said to be the best resolution currently measurable

Summary

HPGe Detector Resolution calculate

- Try to calculate Resolution with rqc,fmax
- After Rebin, 0.0009 is best resolution
- The difference from the manual value is assumed to be due to the dead layer of the crystal
- It will be useful for future experiment

2023 Researches

Jiwon Seo

HEP Center 2023 Winter Workshop
2023.12.27 ~ 2023.12.28 | 곤지암 리조트

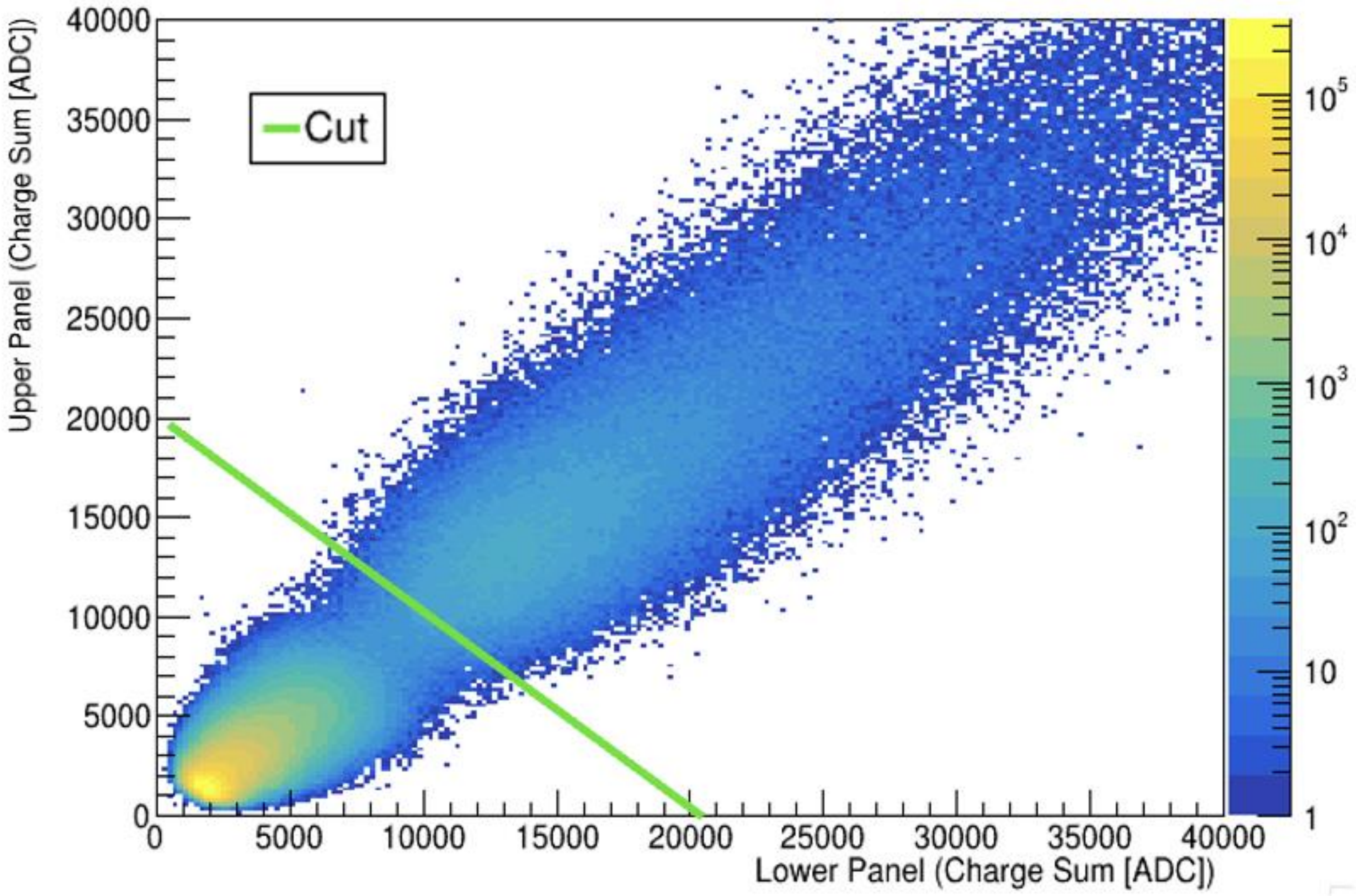
Muon selection criteria & Height, length relation

Korean topographic tomography using a muon detect

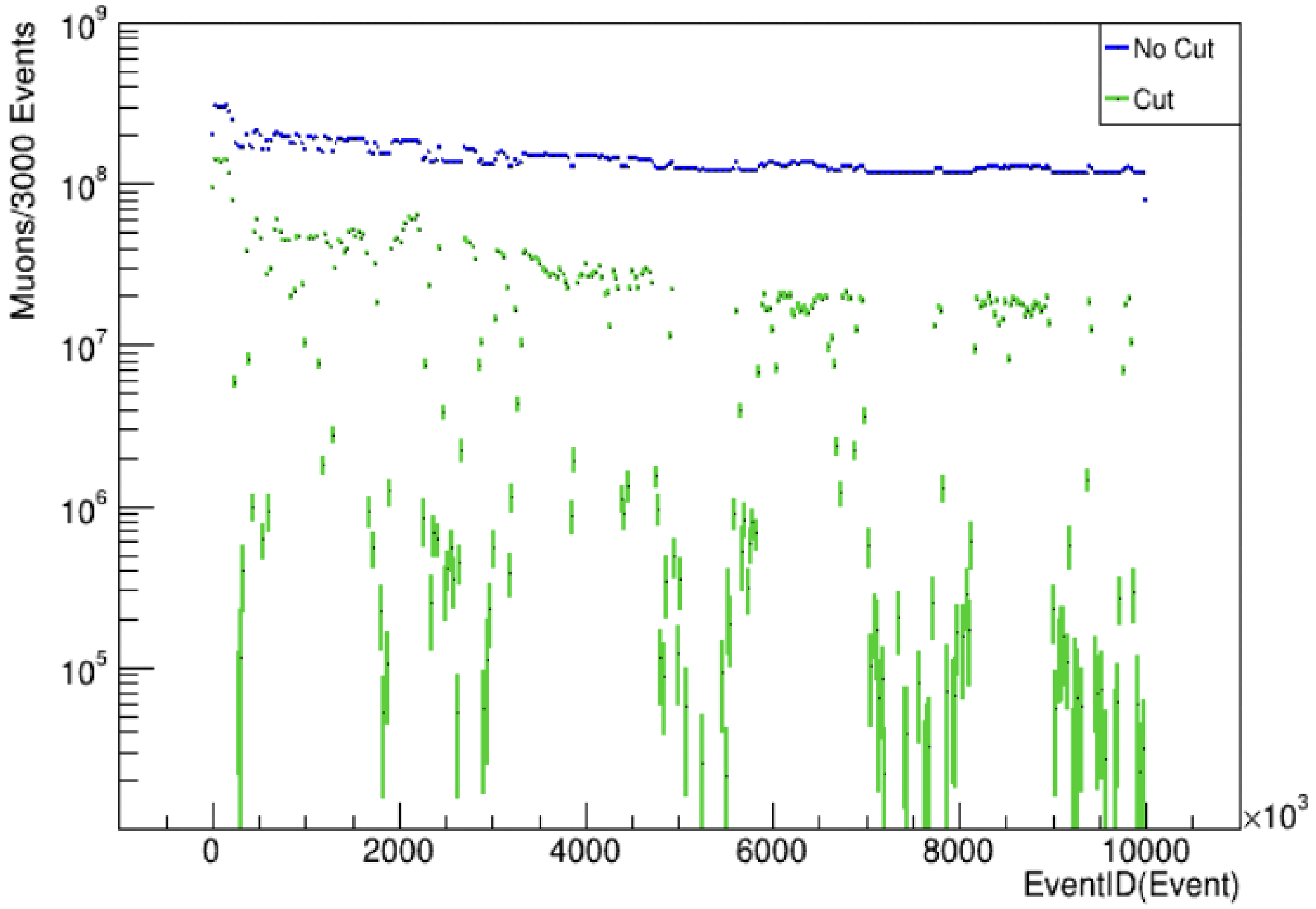
Detector Efficiency

Muon Event / Total Event = 0.9304

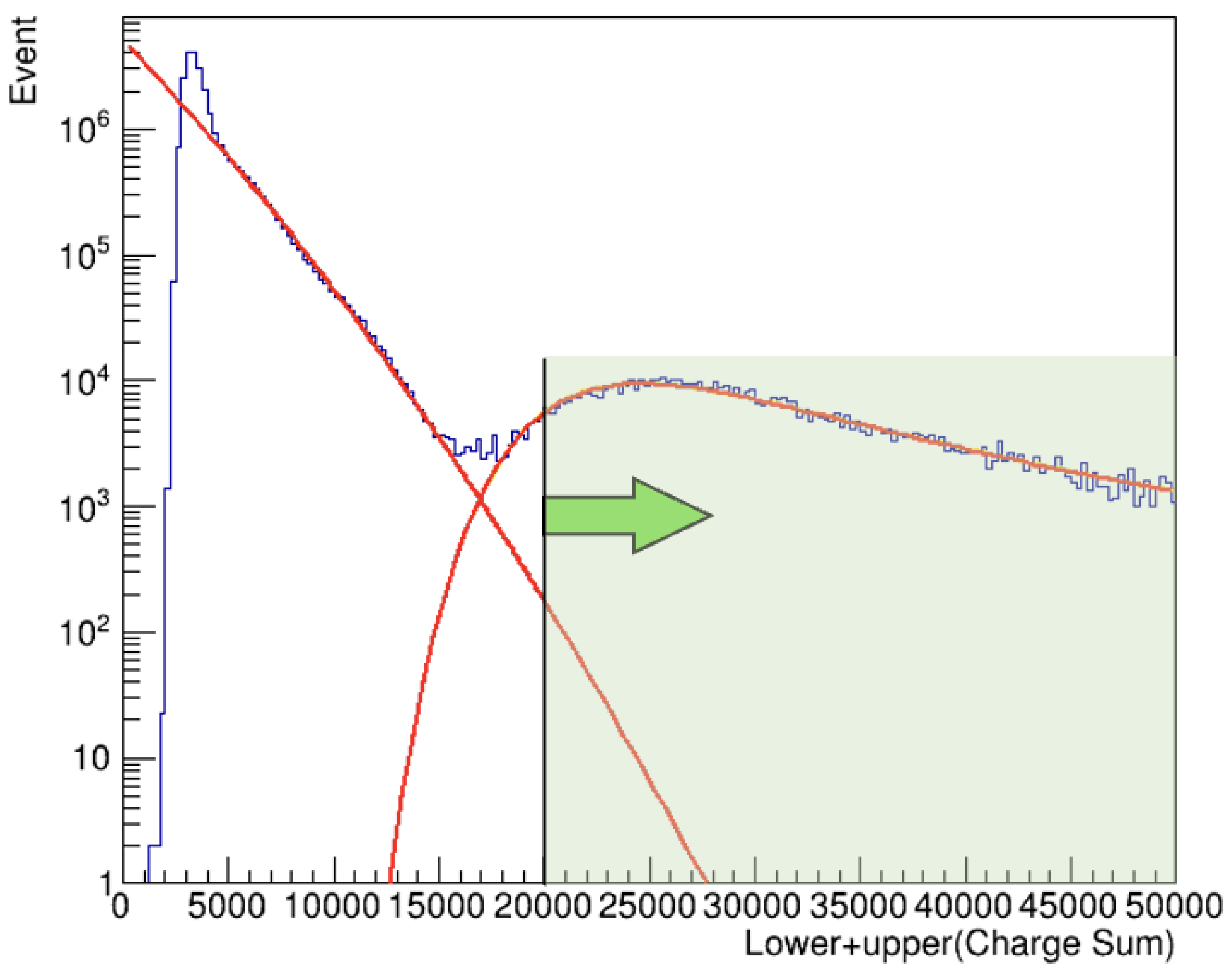
Charge Distribution(2D)

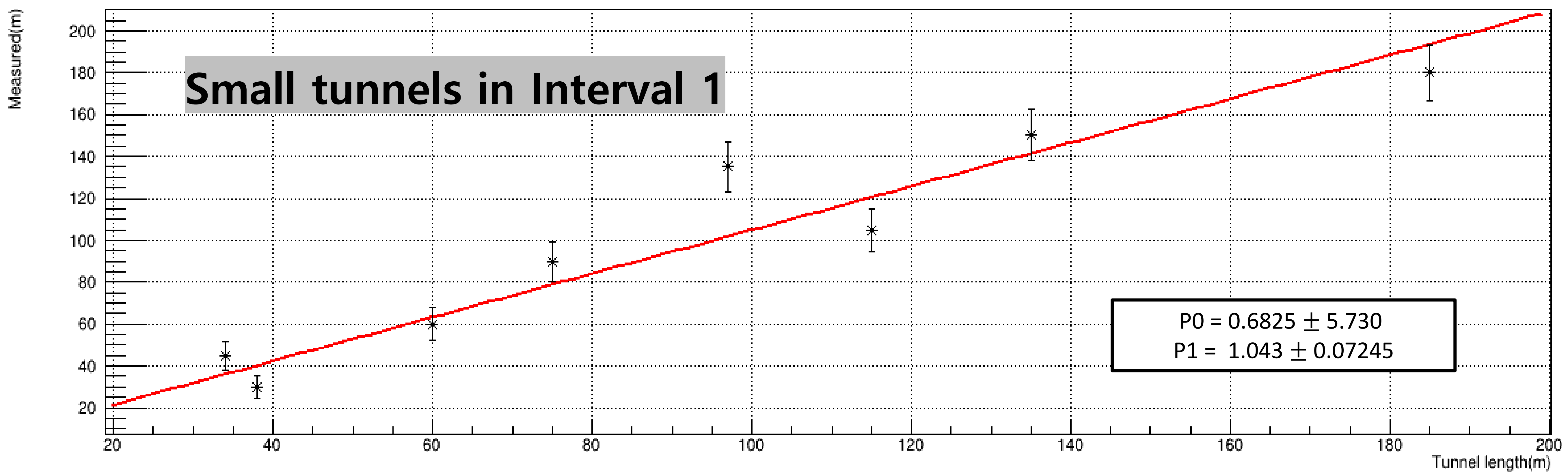


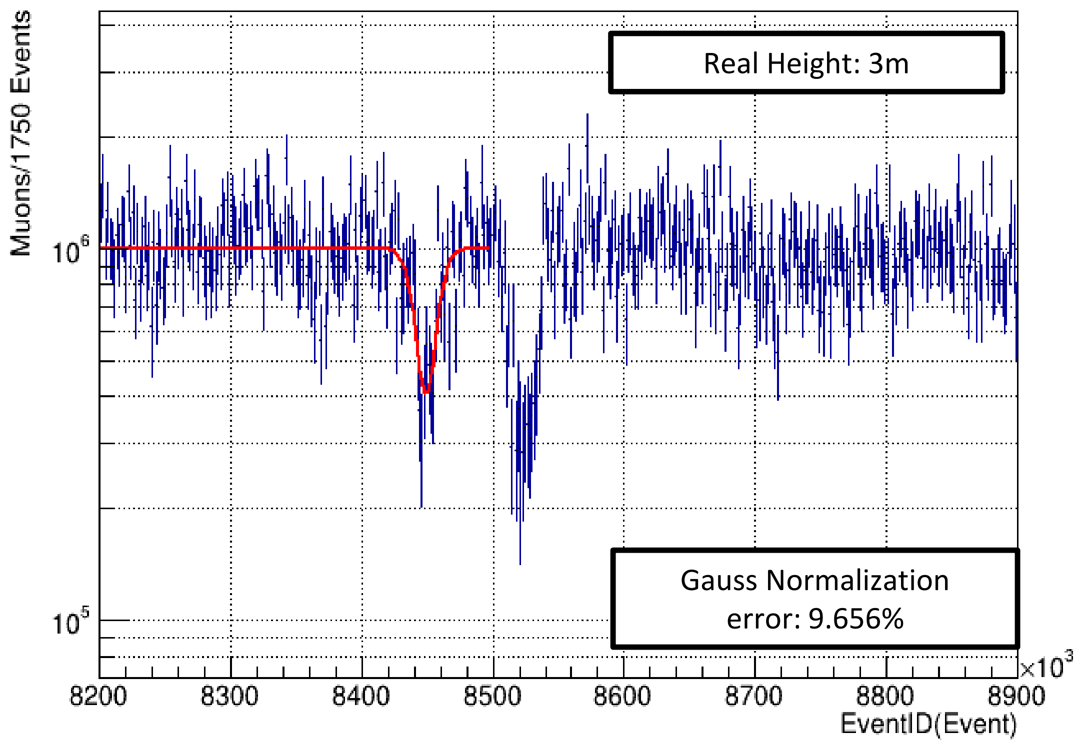
Muon Count

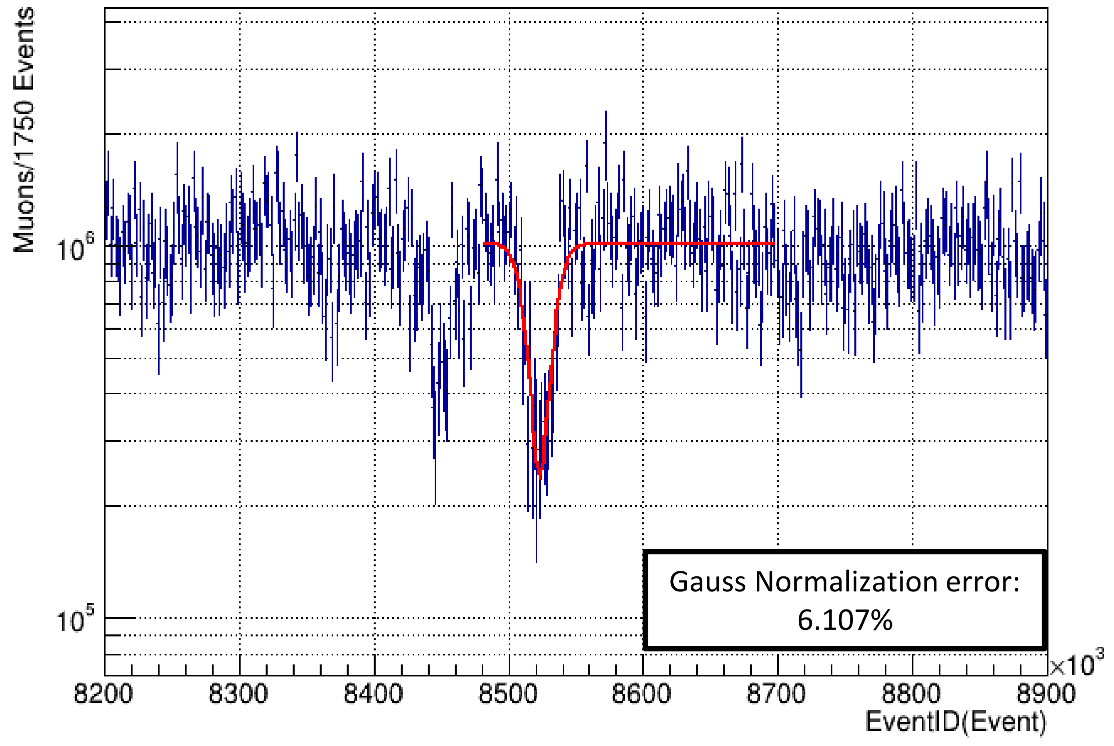


Total Charge





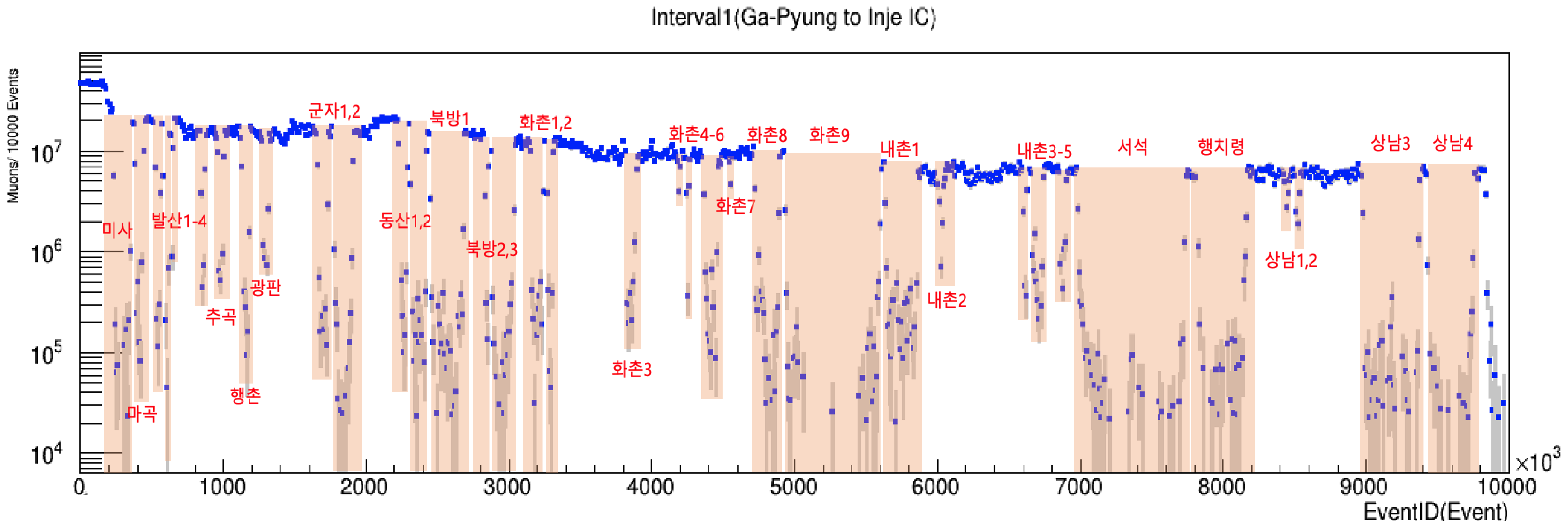




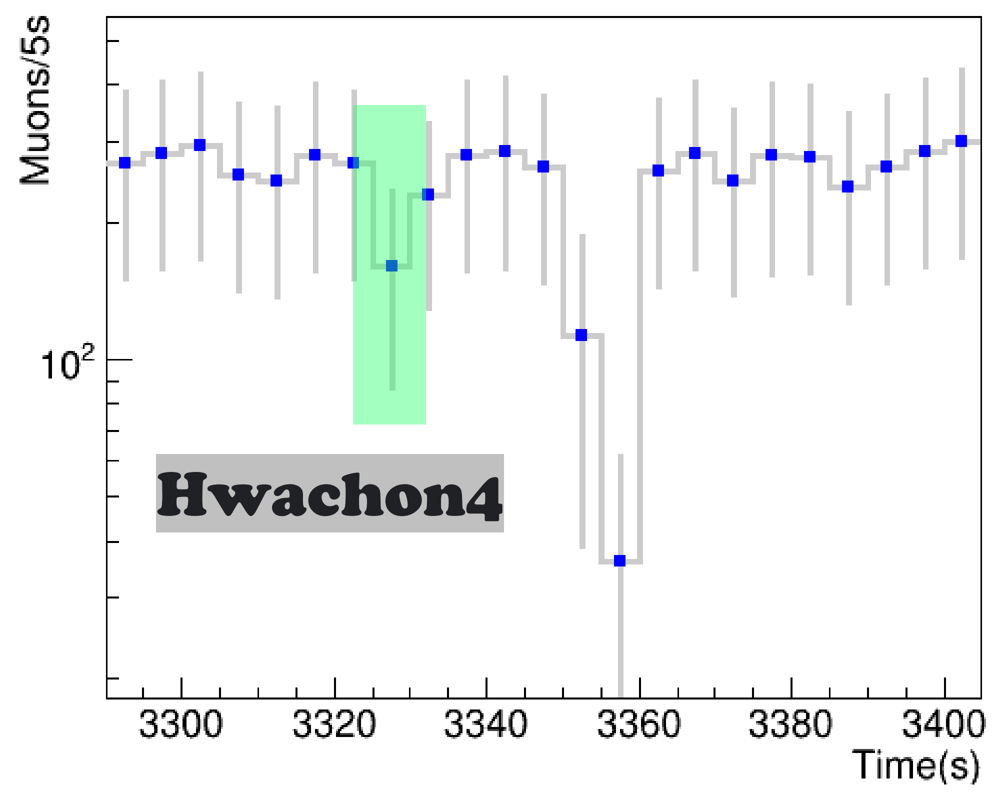
Precision of 8% at around 3 meter

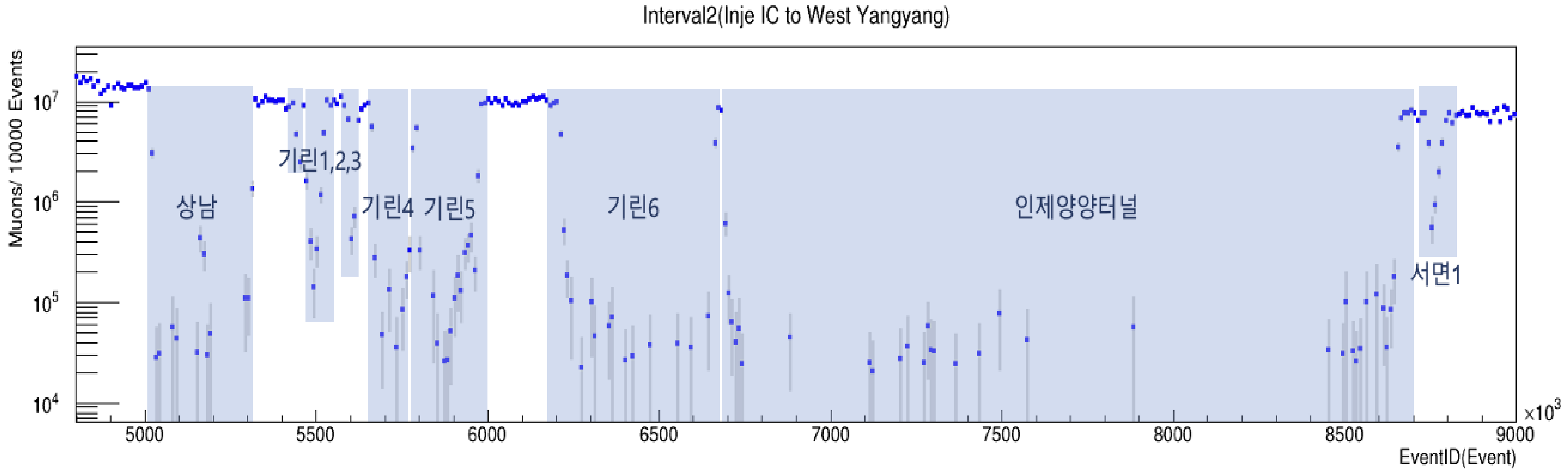
Tunnel matching

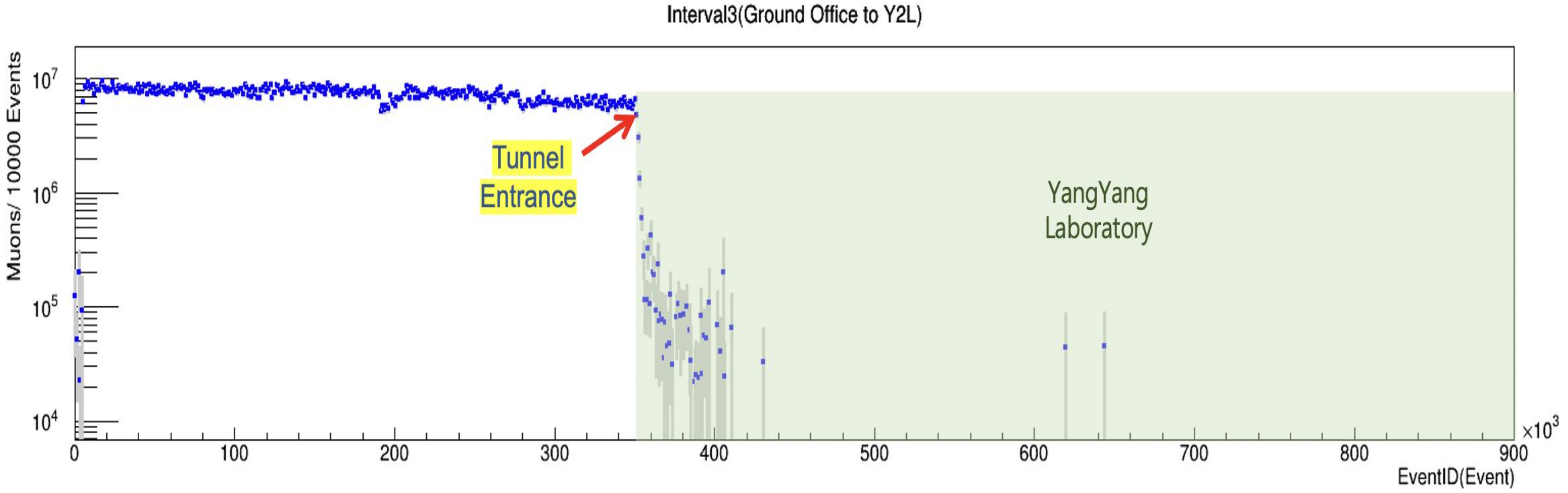
Korean topographic tomography using a muon detector



The Shortest tunnel



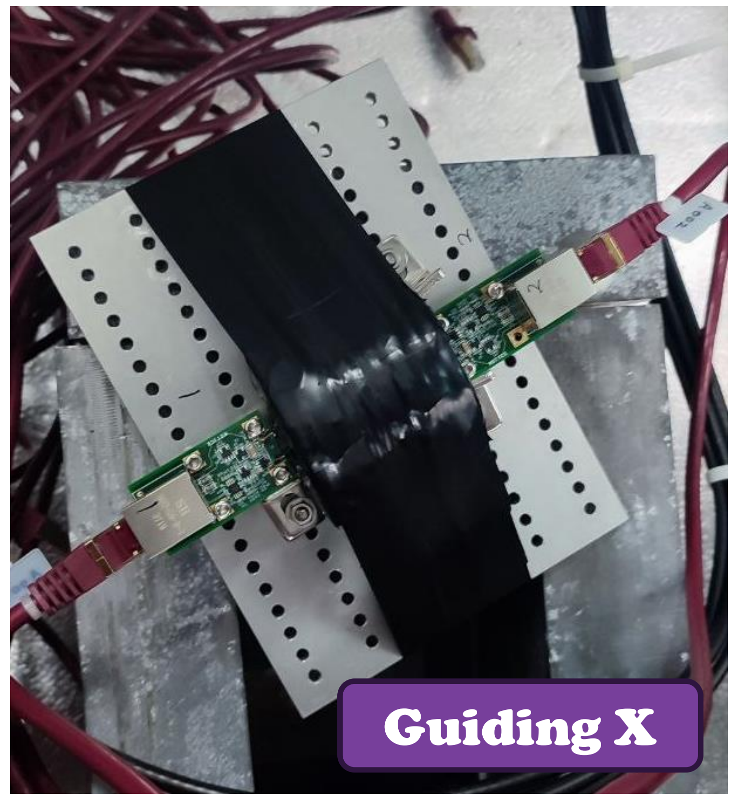


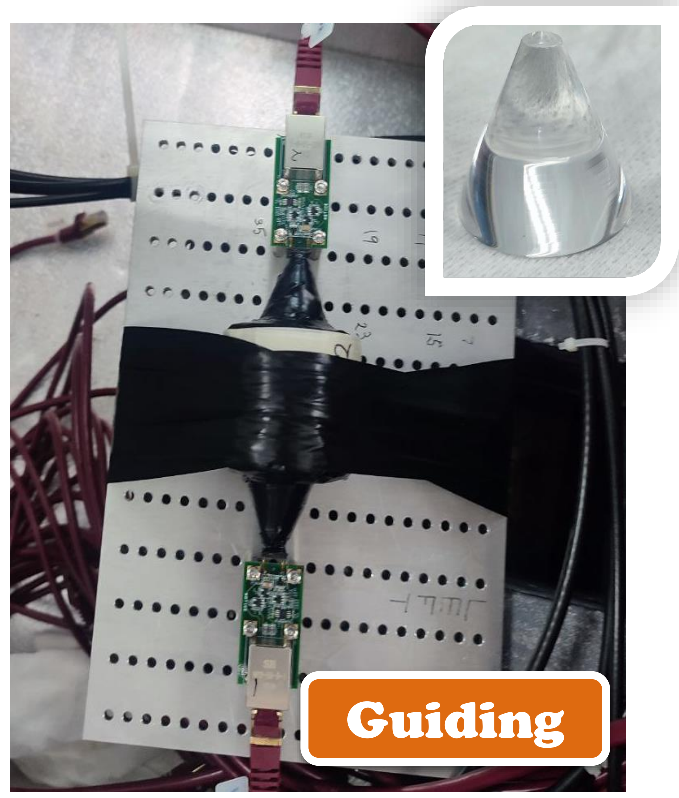


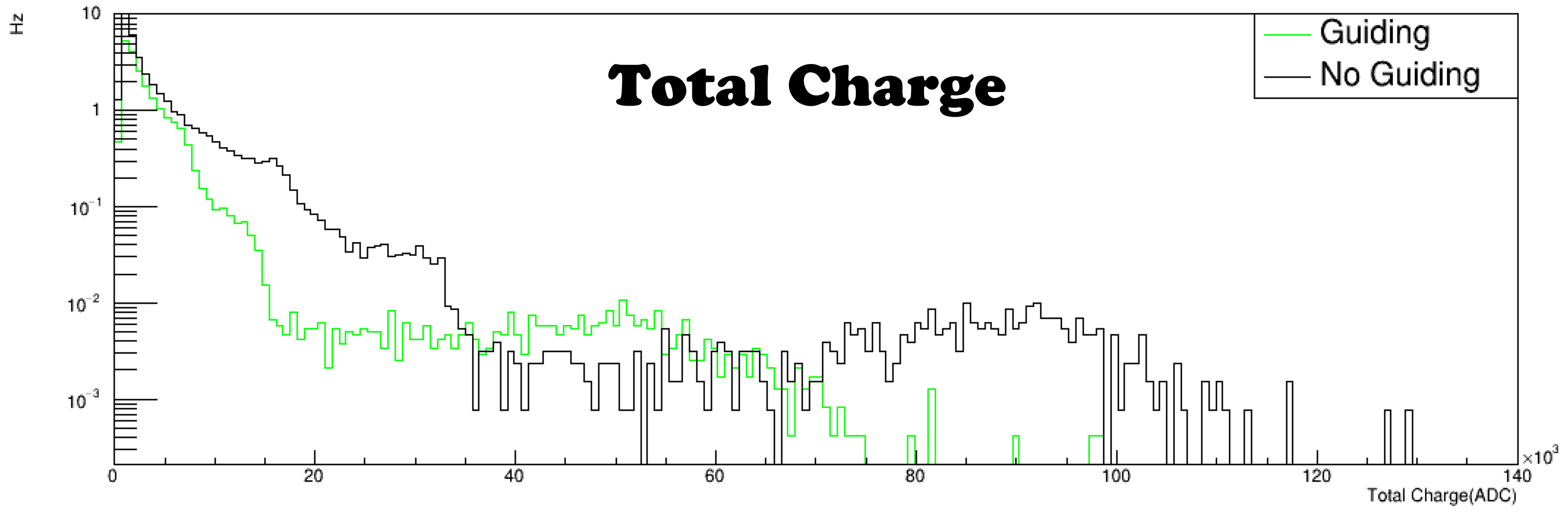
Test

Development of a compact, portable muon detector for landscaping

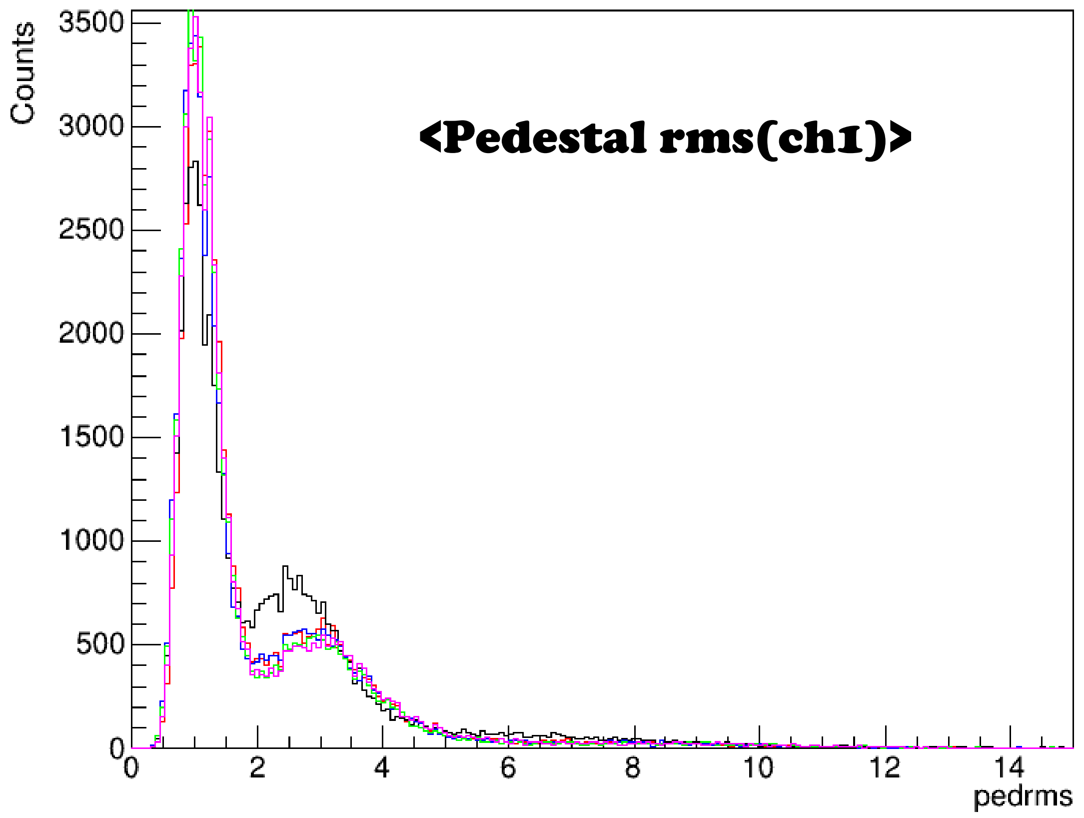
1. Guiding



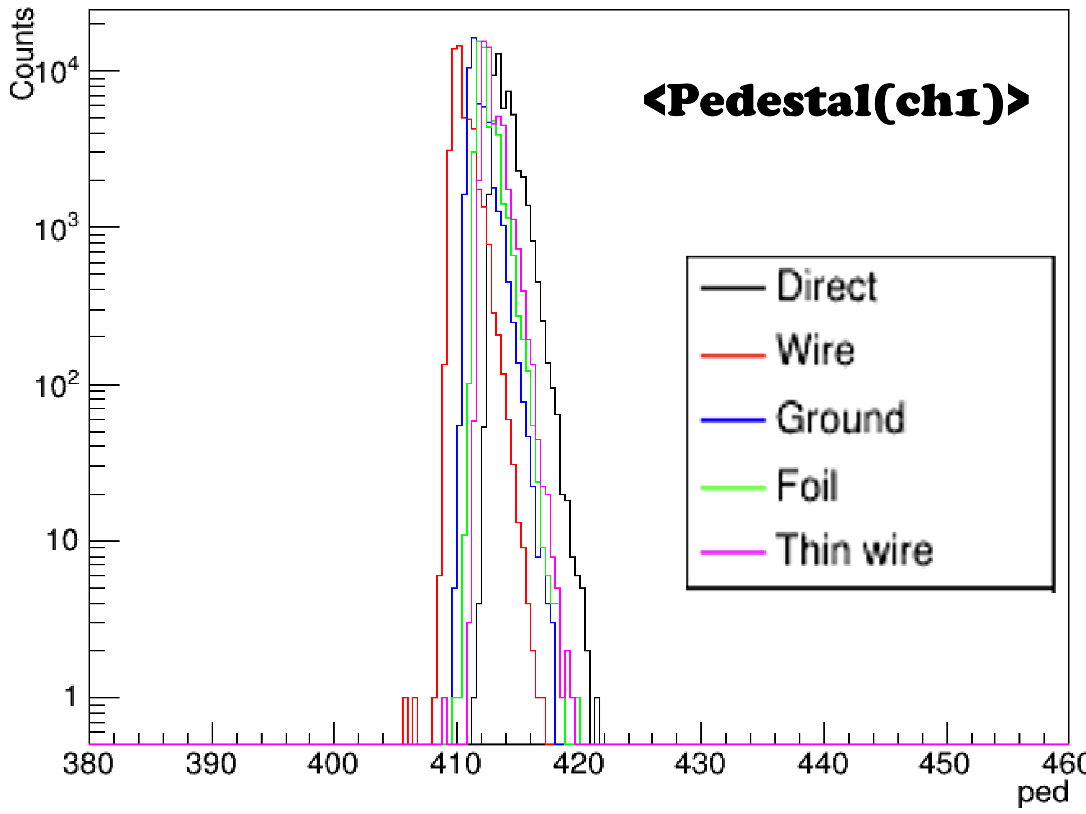




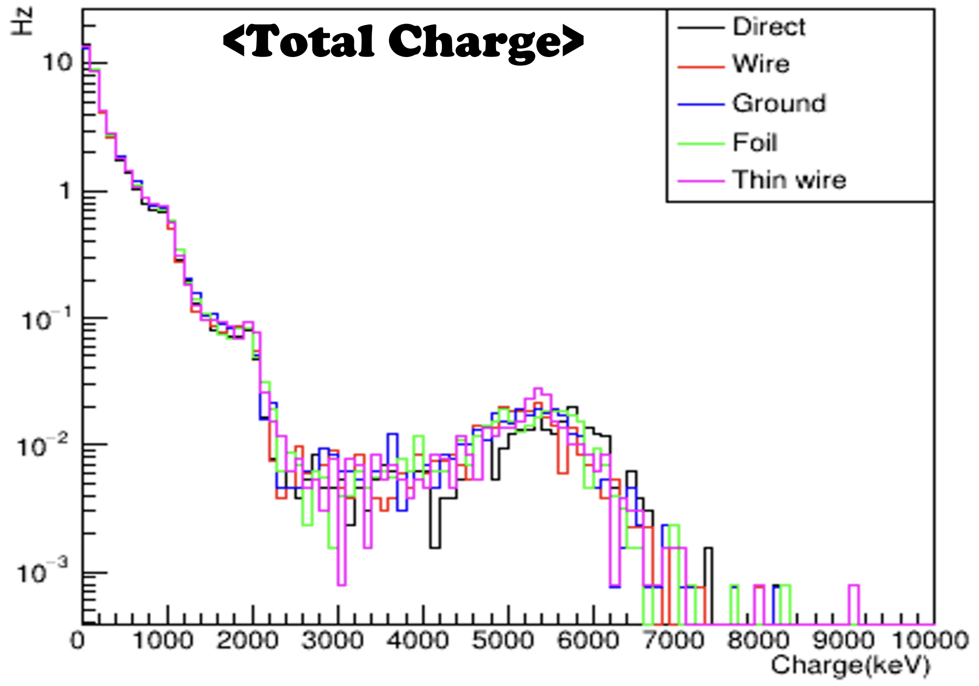
2. Wire

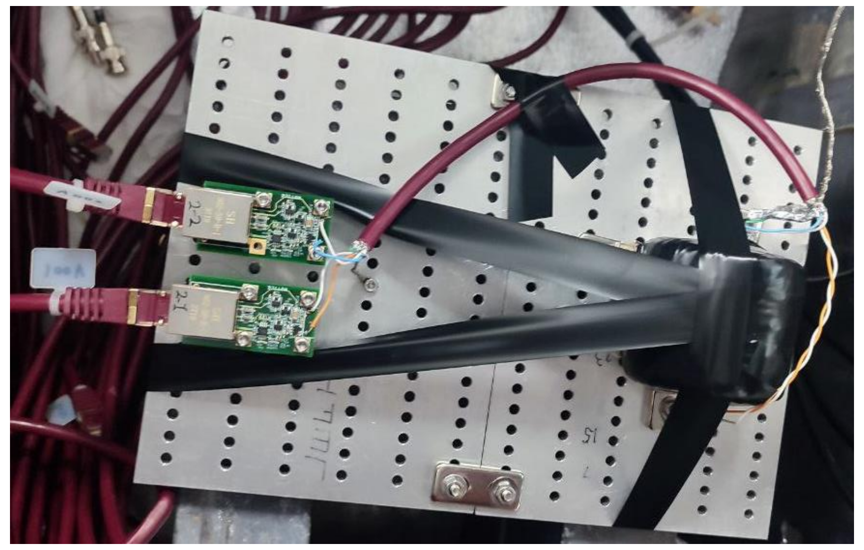


	Direct	Wire	Ground	Foil	Thin
mean	2.26	2.047	2.013	1.973	2.034
rms	1.903	1.698	1.73	1.734	1.775

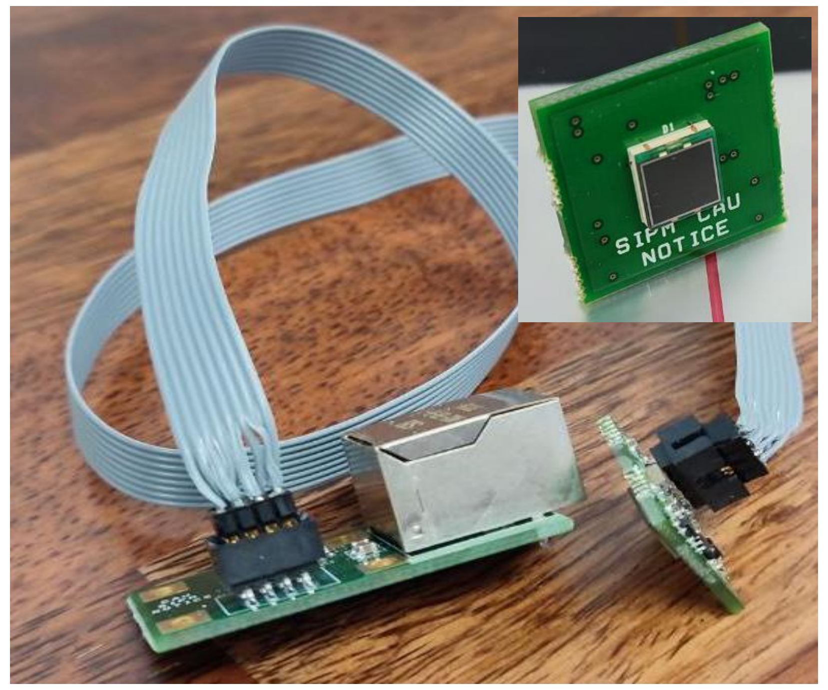


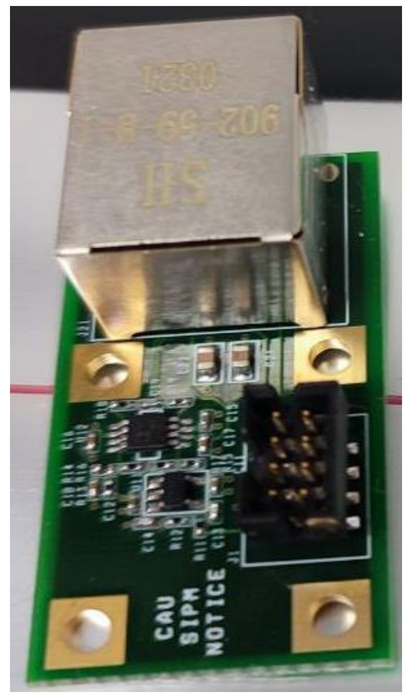
	Direct	Wire	Ground	Foil	Thin wire
mean	413.9	410.4	411.8	412.4	412.9
rms	0.9512	0.8199	0.8228	0.7950	0.7998

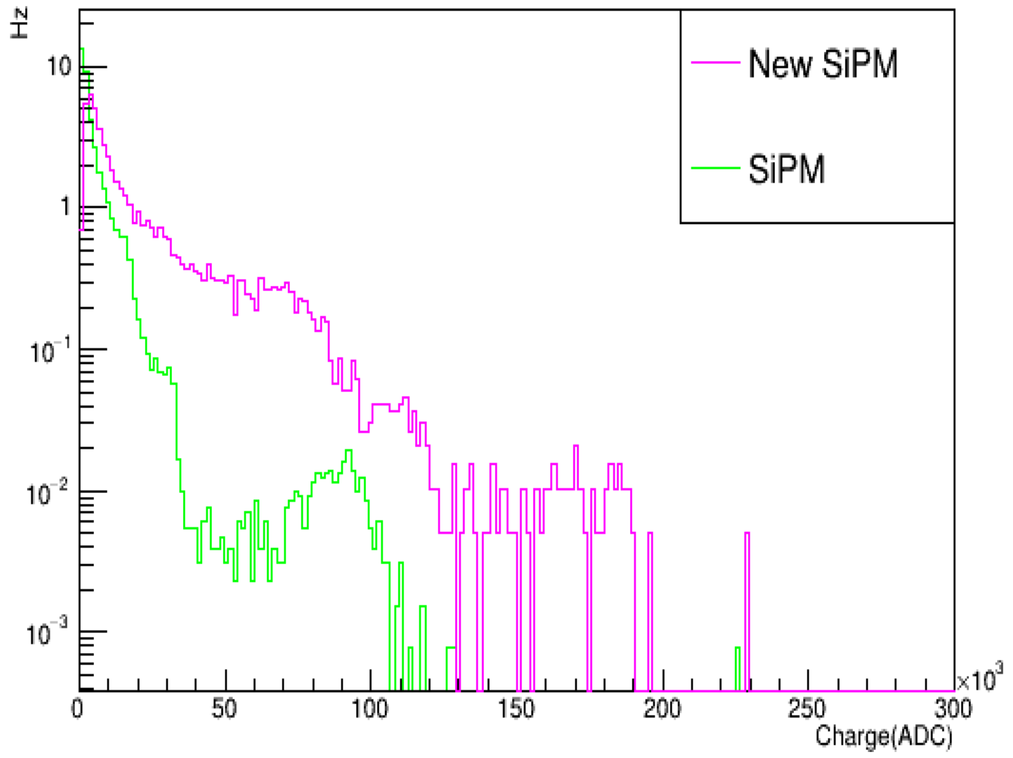


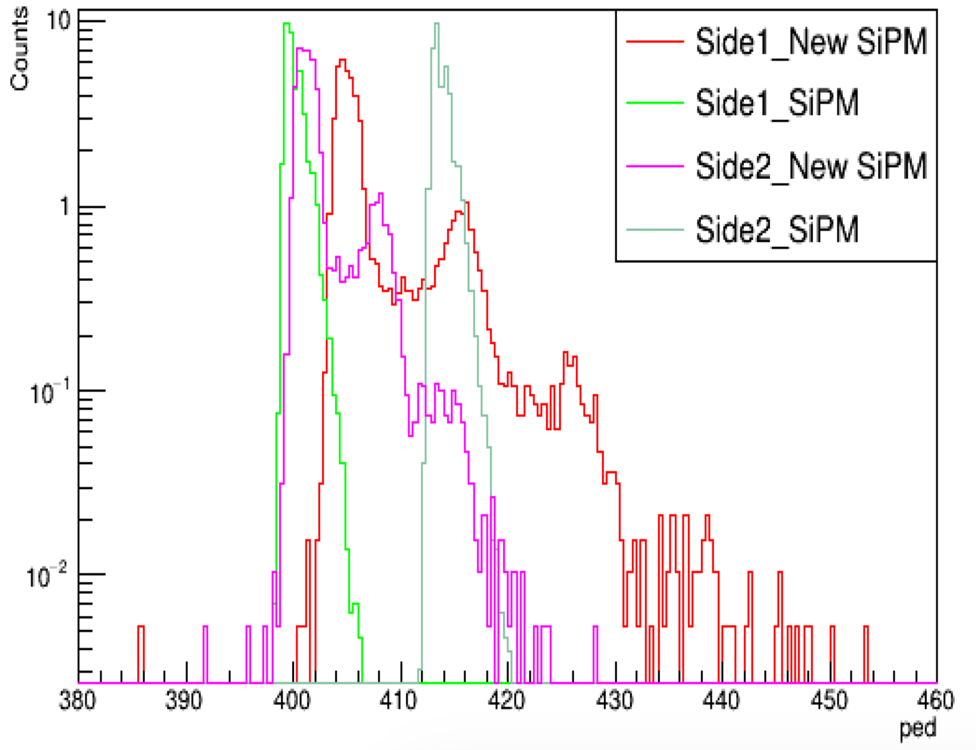


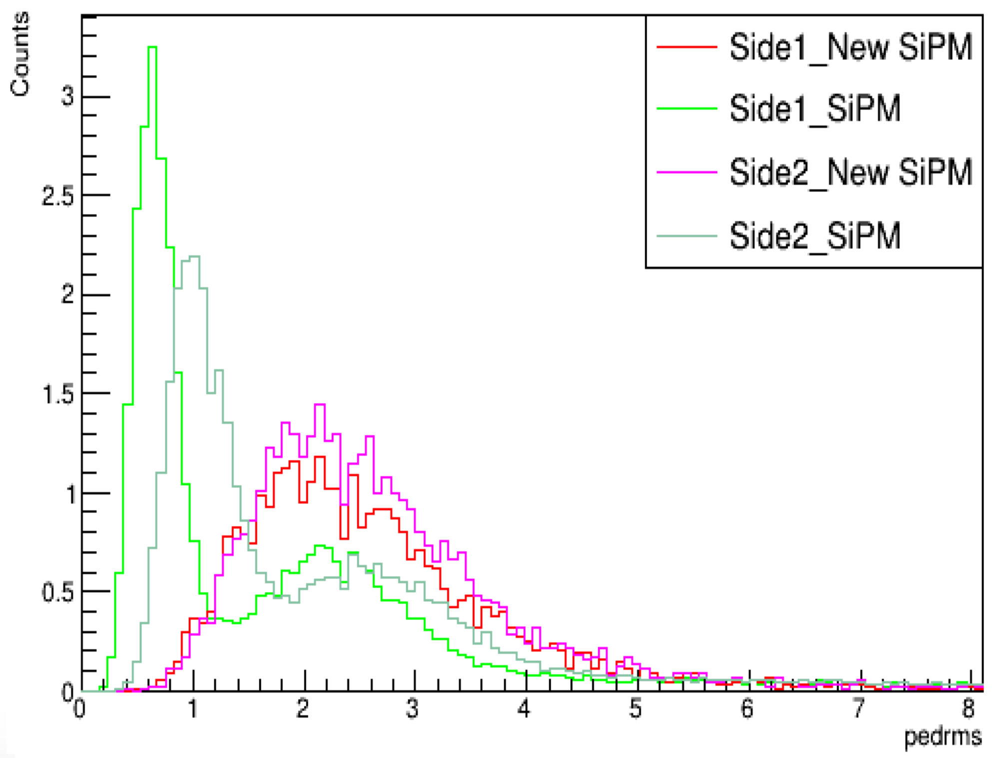
3. New SiPM board





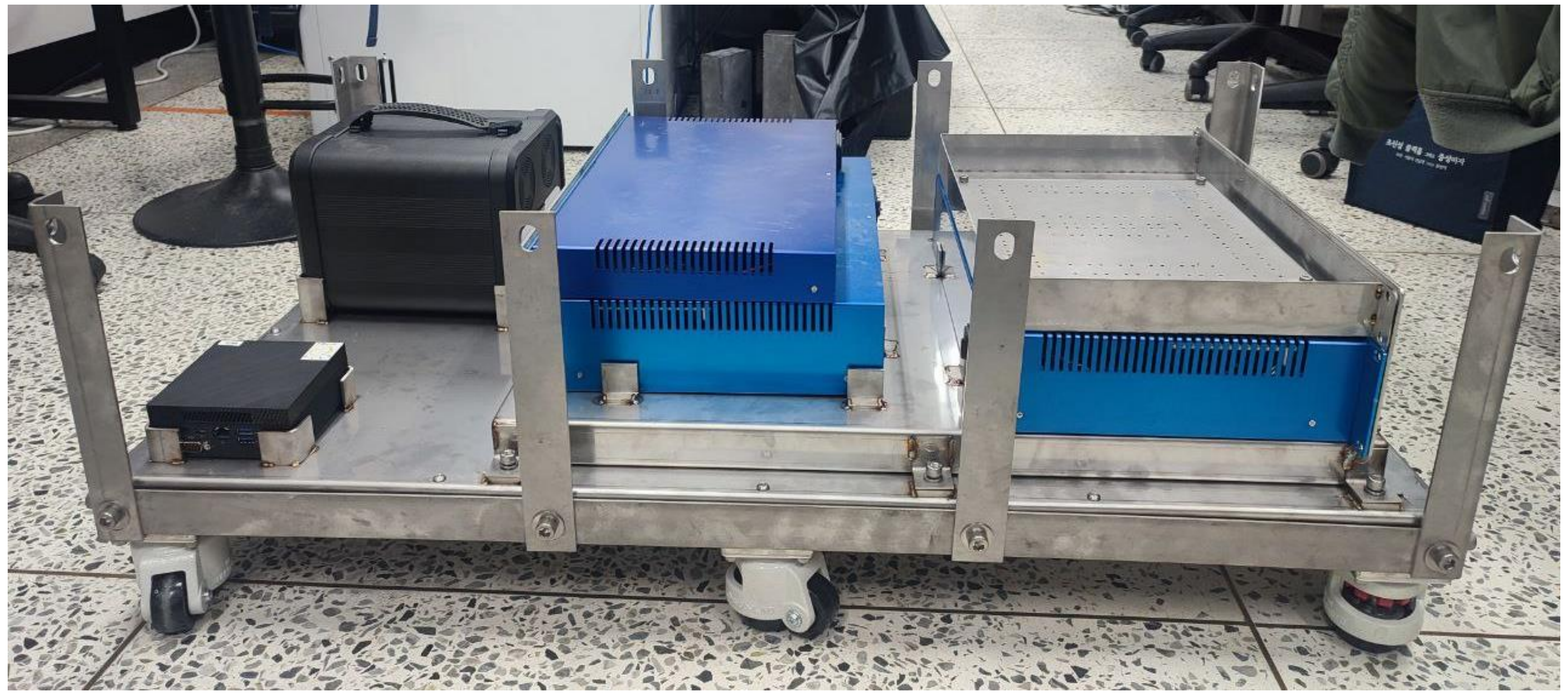




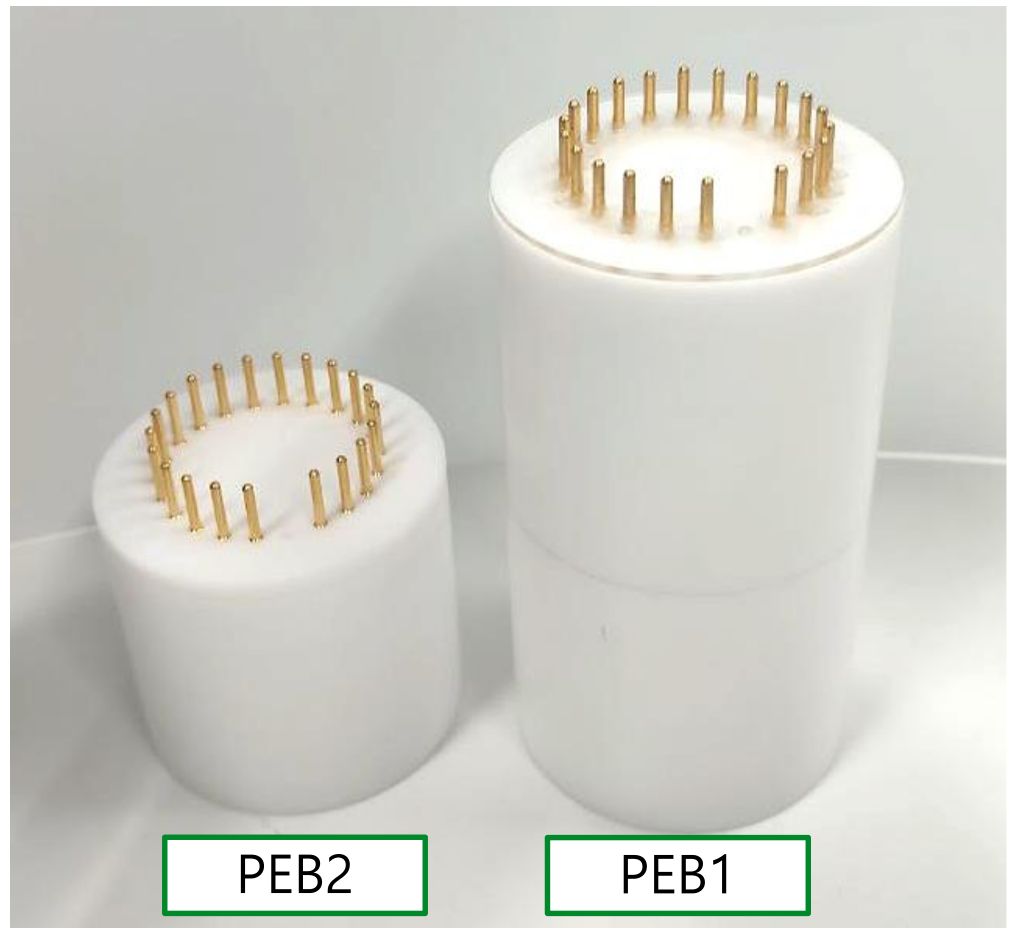


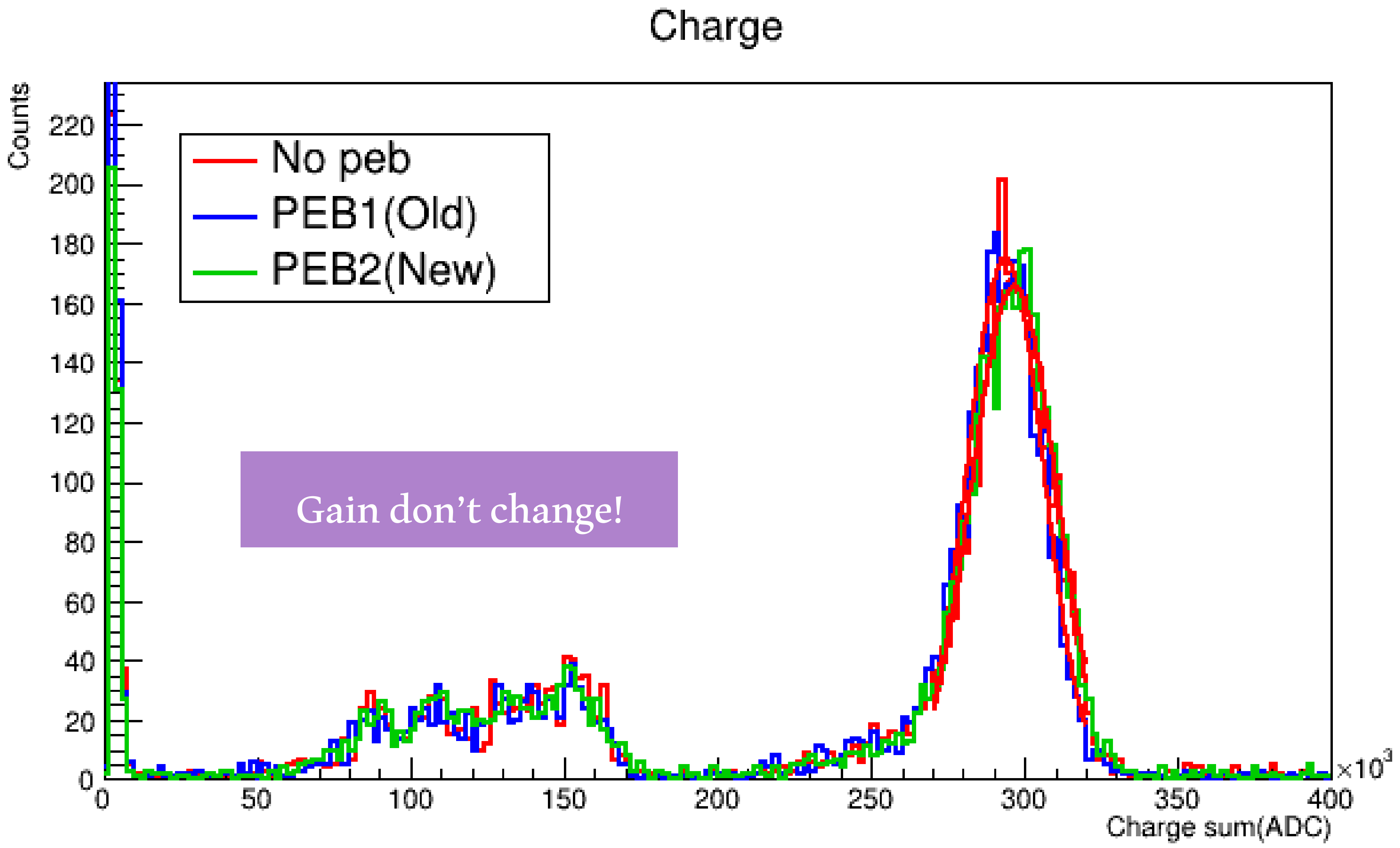
Making

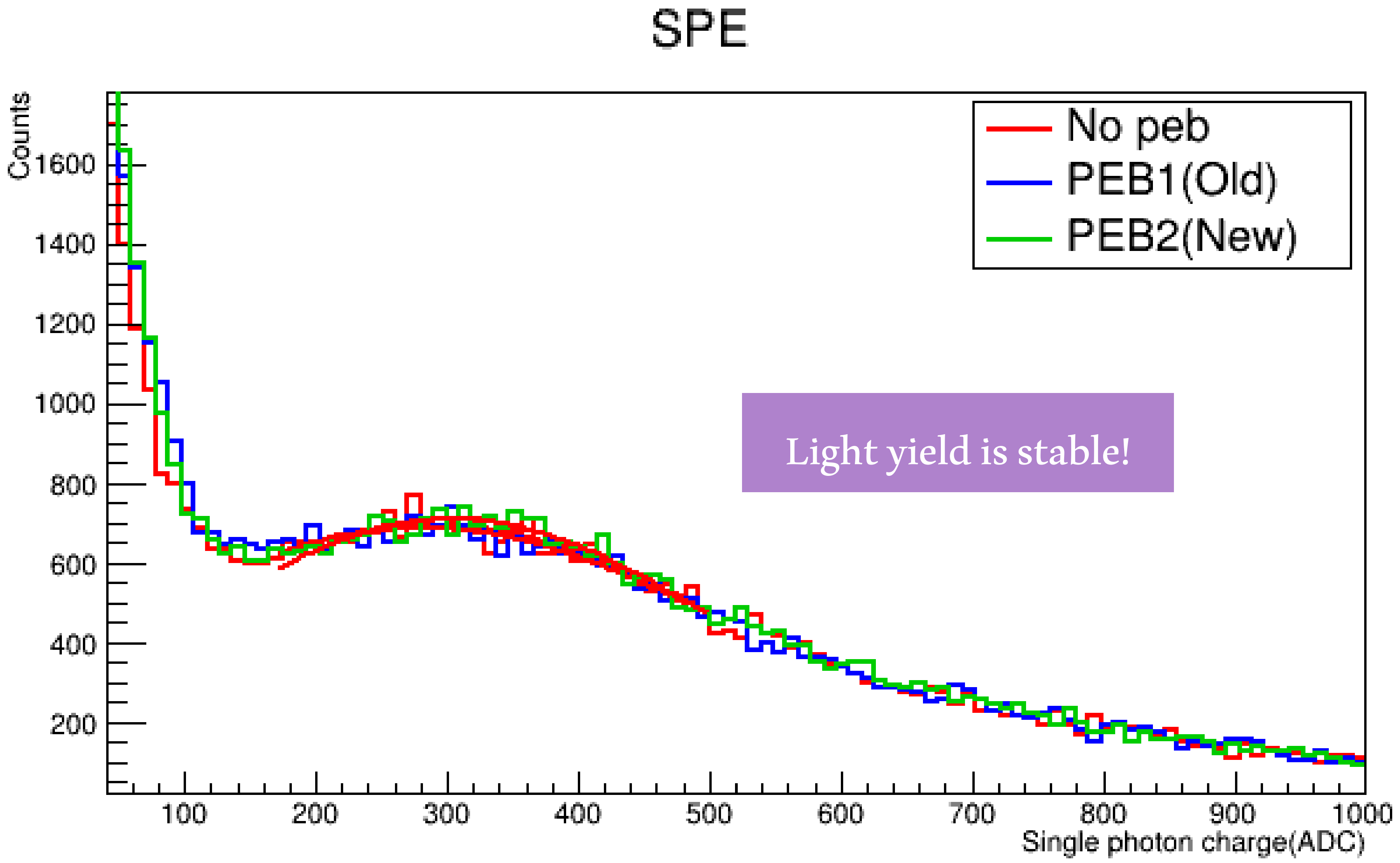
Development of a compact, portable muon detector for landscaping

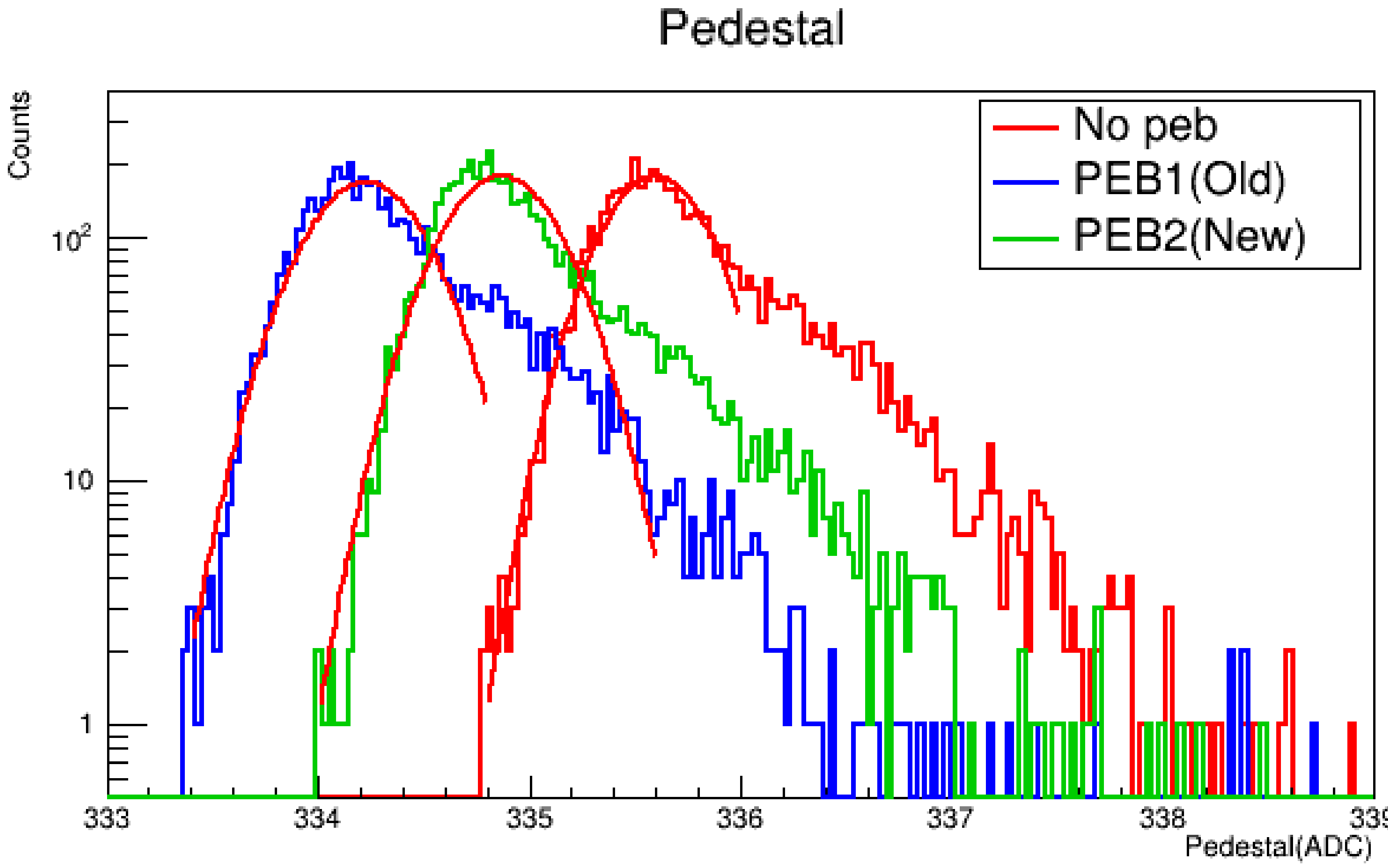


Setting & Result
Extended base2



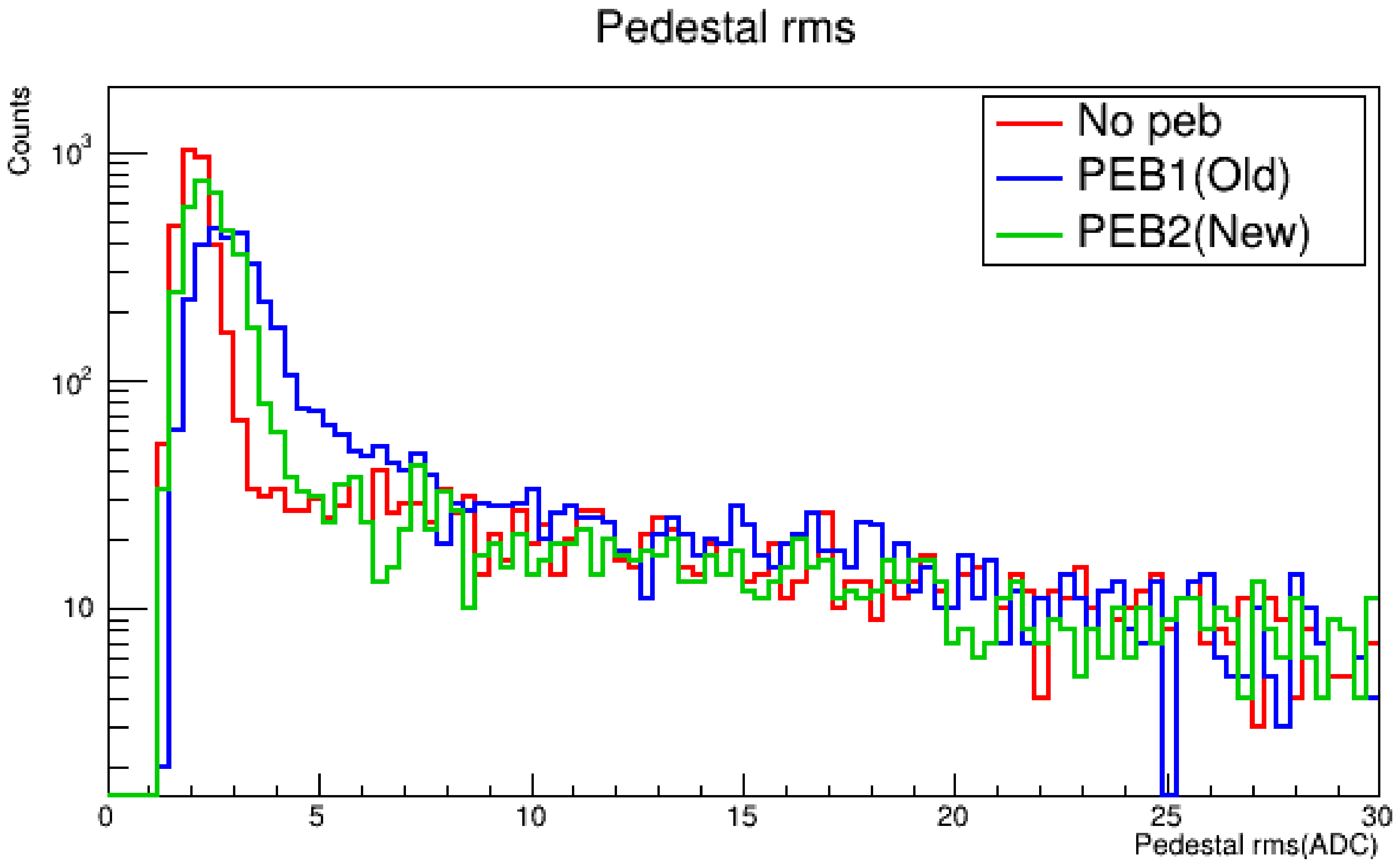






Event by event Pedestal fluctuations are stable!

	Nopeb	Peb1	Peb2
RMS	0.517	0.522	0.499
Fit Mean	335.6	334.2	334.9



Pedestal fluctuations within events are stable! (in PEB2)

	Nopeb	Peb1	Peb2
Mean	5.725	6.743	5.609
RMS	6.614	6.453	6.339

Summary

Korean topographic tomography using a muon detector

- Topography was scanned and reconstructed with high precision(about 50 tunnels).
- Minimum of 2meters for height, and minimum of 34meters for length was achieved.

Development of a compact, portable muon detector for landscaping

- Light efficiency of guiding structure is not better than direct attaching ➔ **Guiding structure will not use.**
- **There are no additional noise when Using thin wire.**
- Noise is occurred more because Gain is greater than before. ➔ **Previous resistance values is applied on new board.**
- For compact detector, Devices located between two PS case.

Extended base2

- Background is generated in the base. When the base is extended, it can be reduced.
- 'Gain', 'light yield' and 'Event by event Pedestal fluctuations' are stable!
- Pedestal fluctuations within events are stable when using PEB2 ➔ There are no additional noise(PEB2).

Researches in 2023

Joonbeom Lee

HEP Center 2023 Winter Workshop
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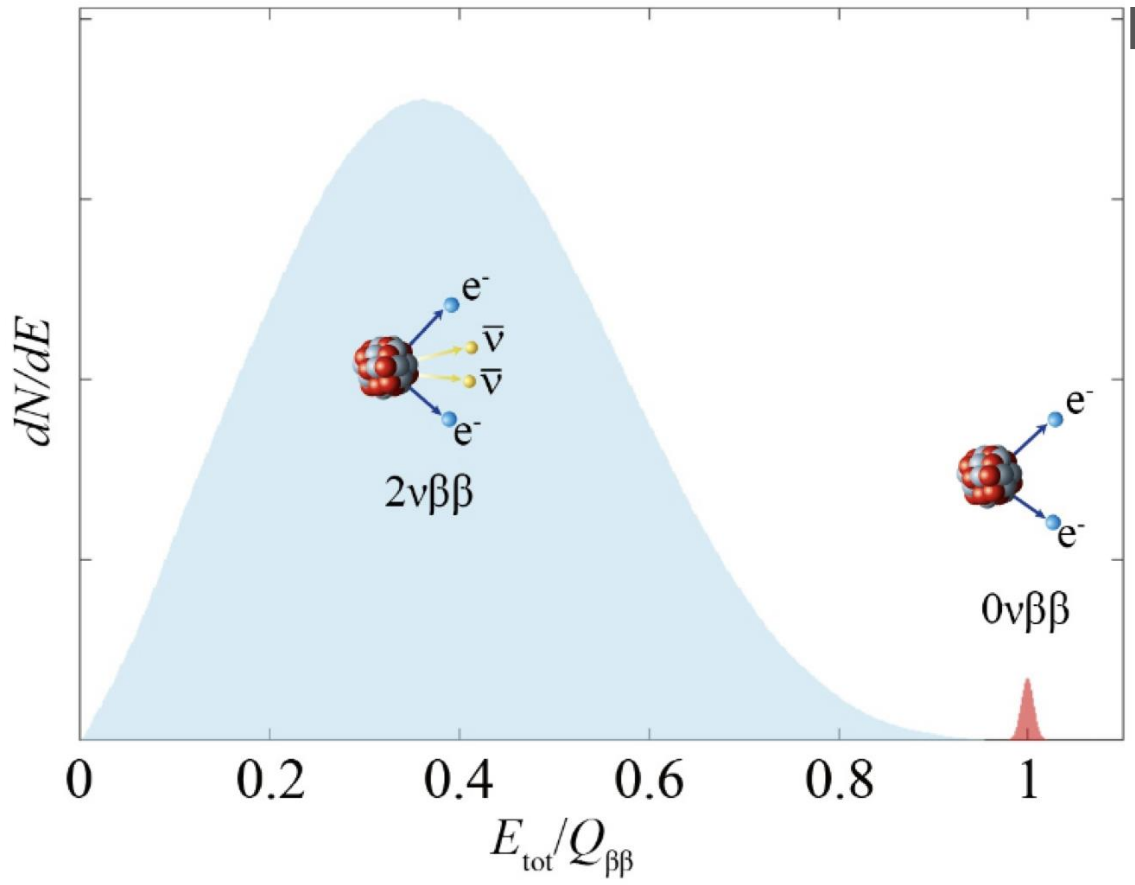
The AMoRE Experiment [Advanced Mo-based Rare process Experiment]
AMoRE / SQUID TEST

The purpose of this experiment is to analyze neutrinoless double beta decay (0νββ) of ^{100}Mo, by using cryogenic particle detector ith highly purified molybdate crystals



Neutrinoless double beta decay (0νββ)

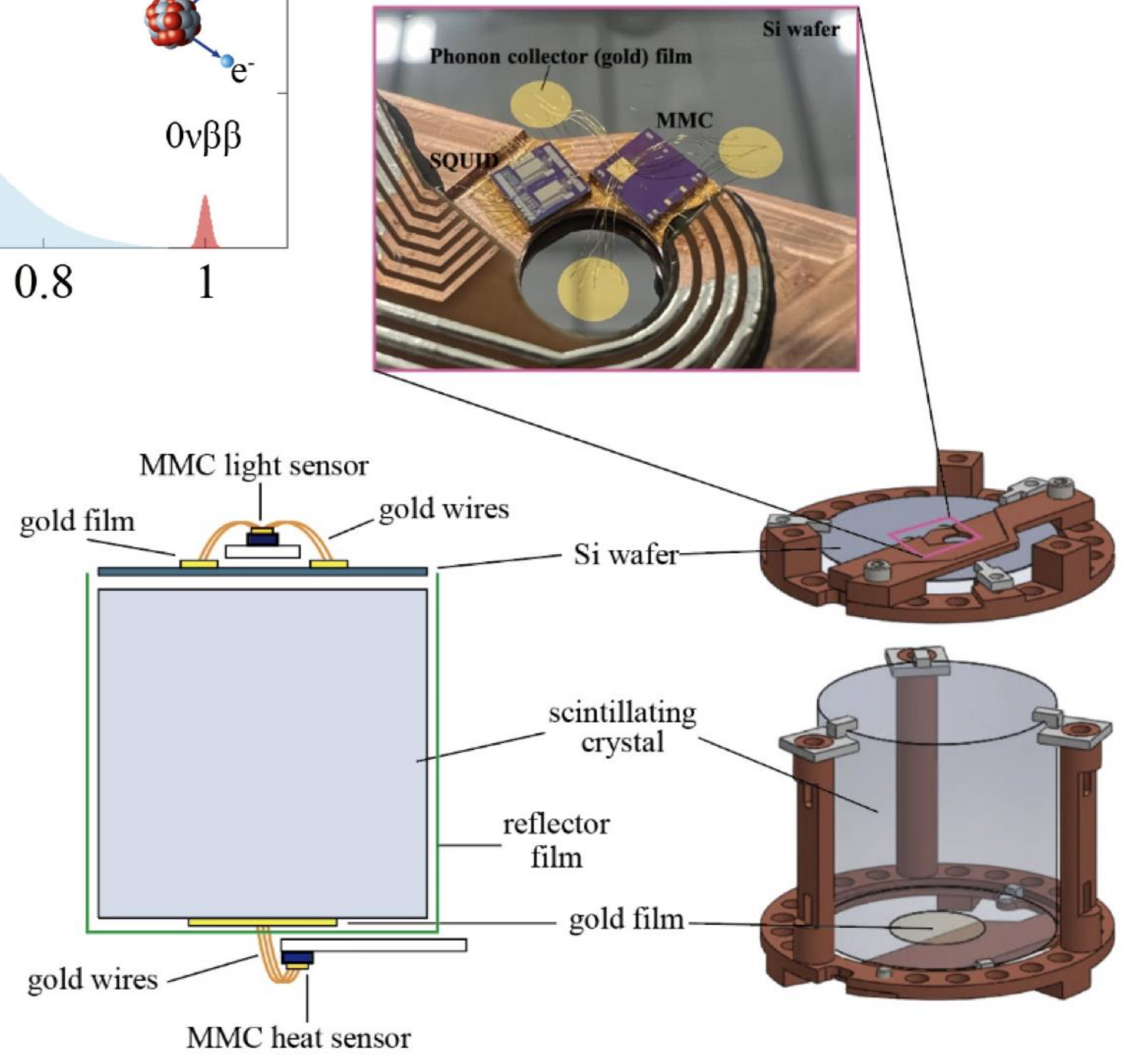
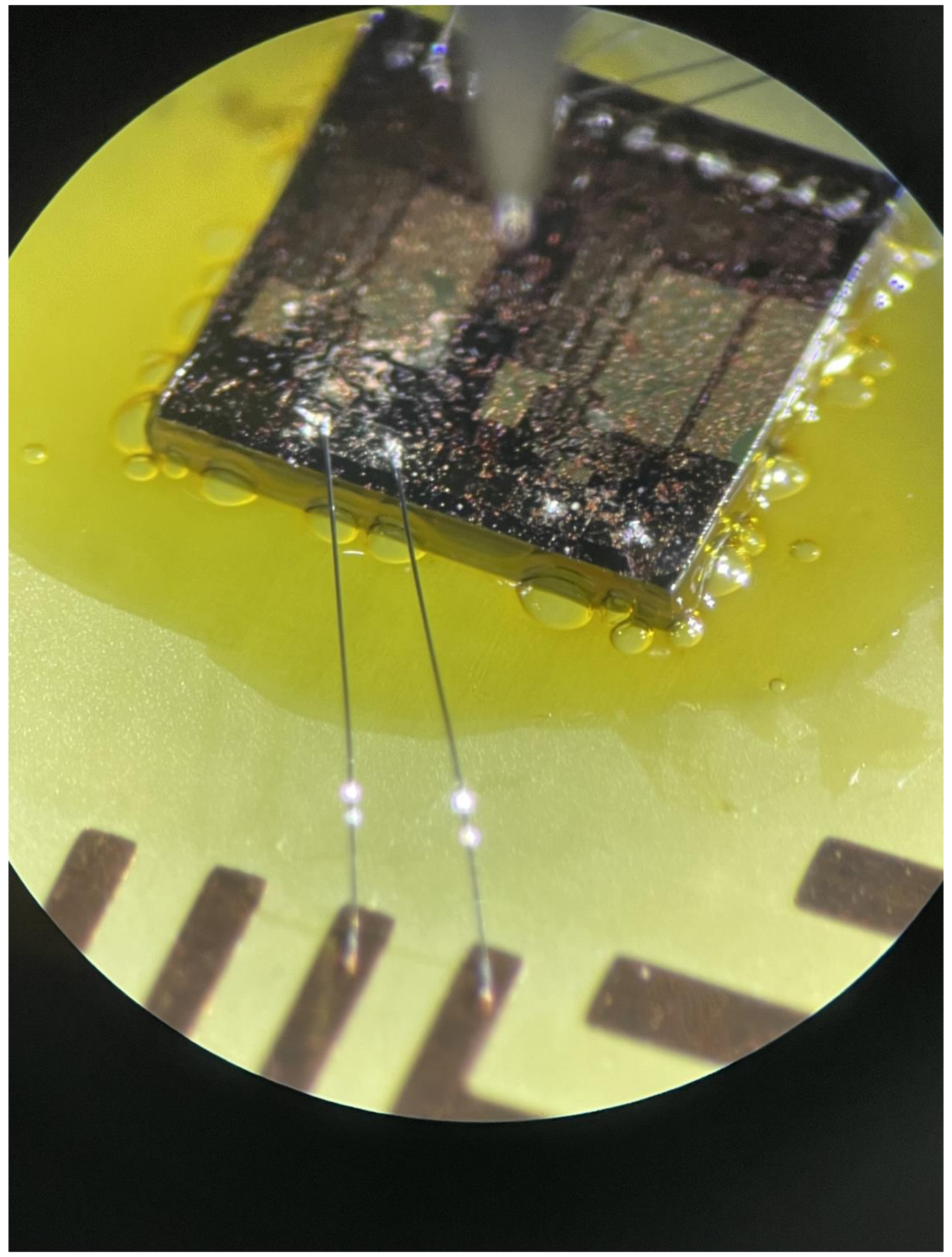
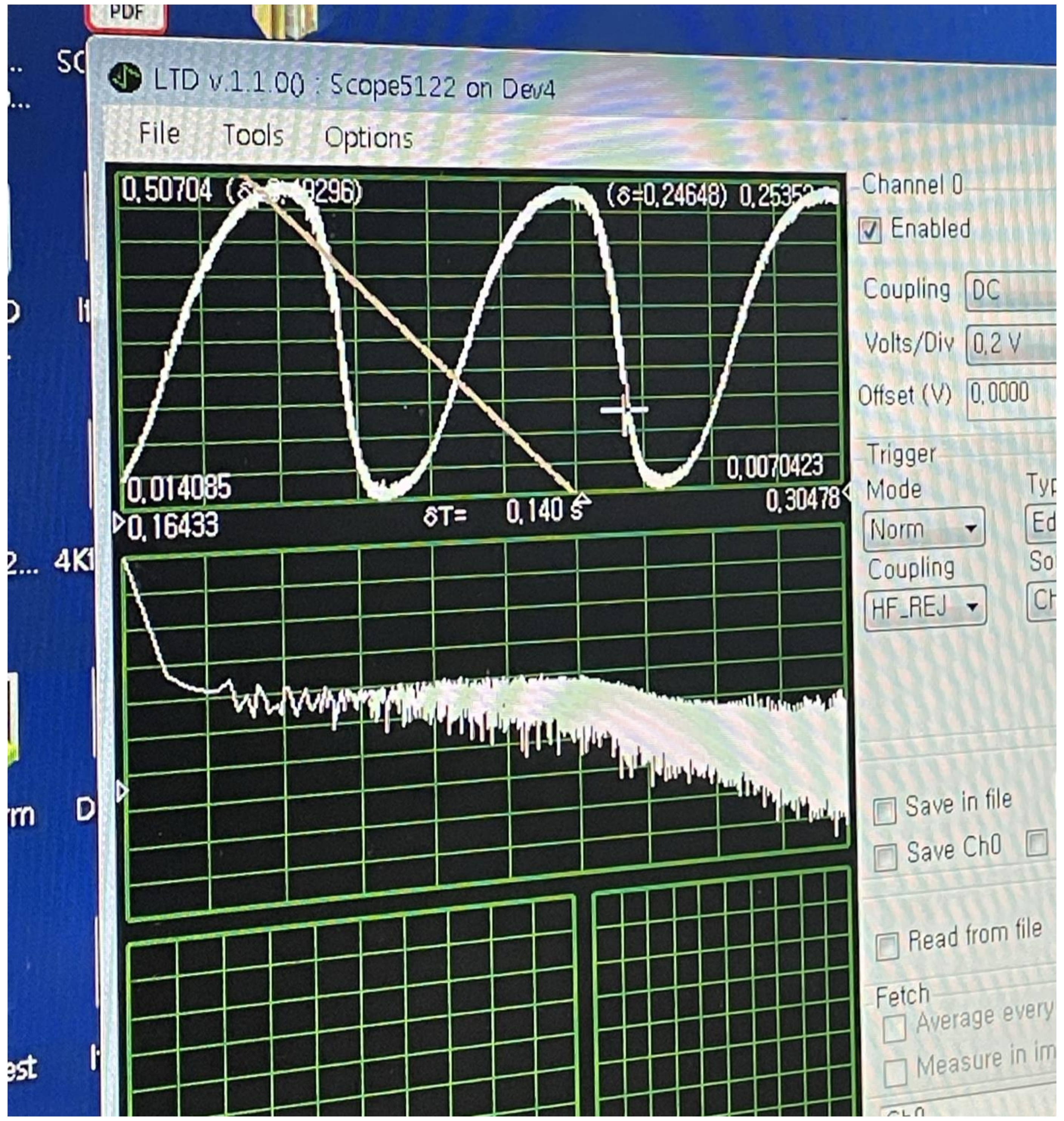


Fig. 2. The AMoRE module design with a picture of a light sensor used for simultaneous heat and light detection. This design is for a scintillating crystal in 5 cm diameter and 5 cm height.



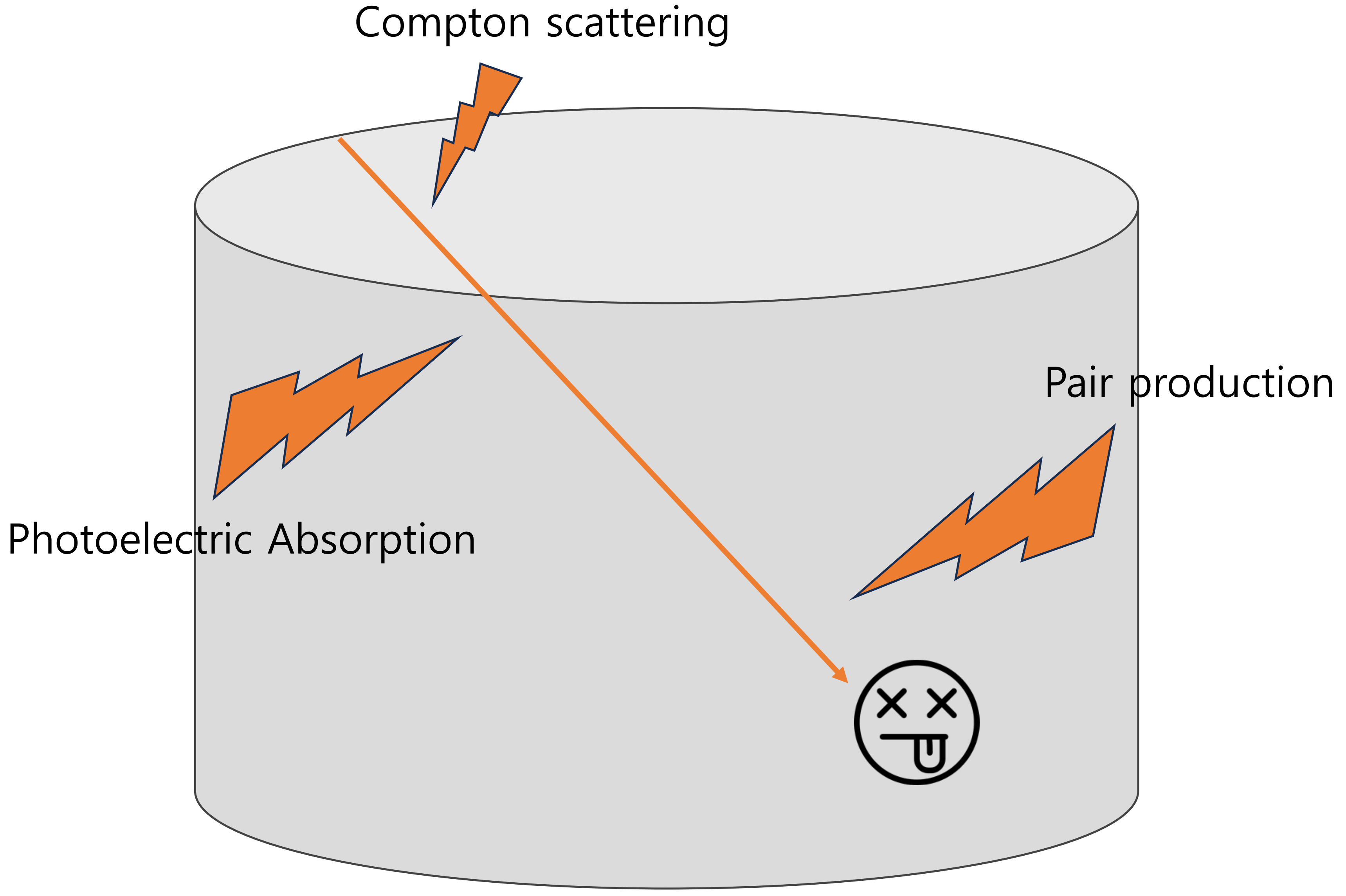
SQUID bonding



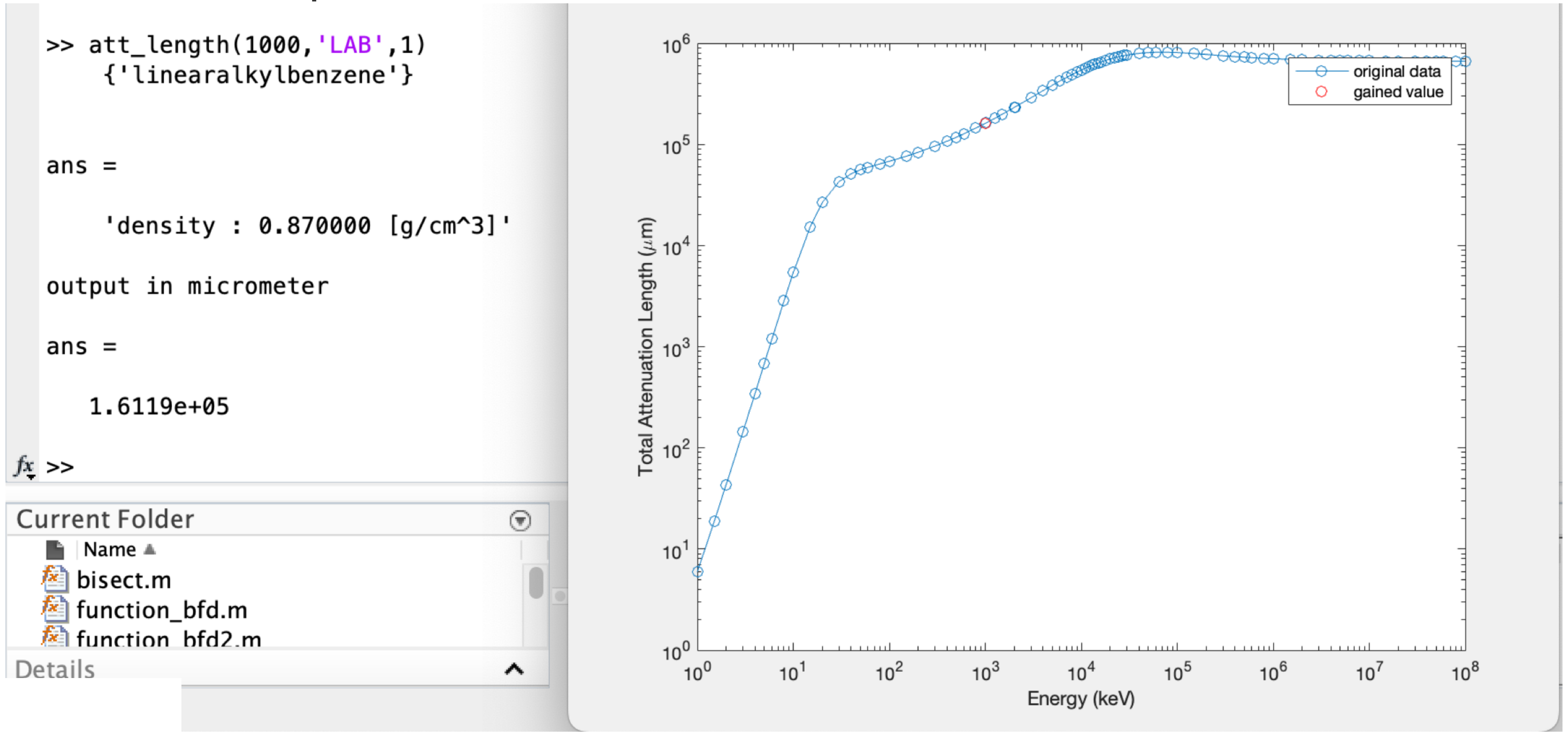
SQUID performance test

The AMoRE Experiment

Attenuation length Common function develop

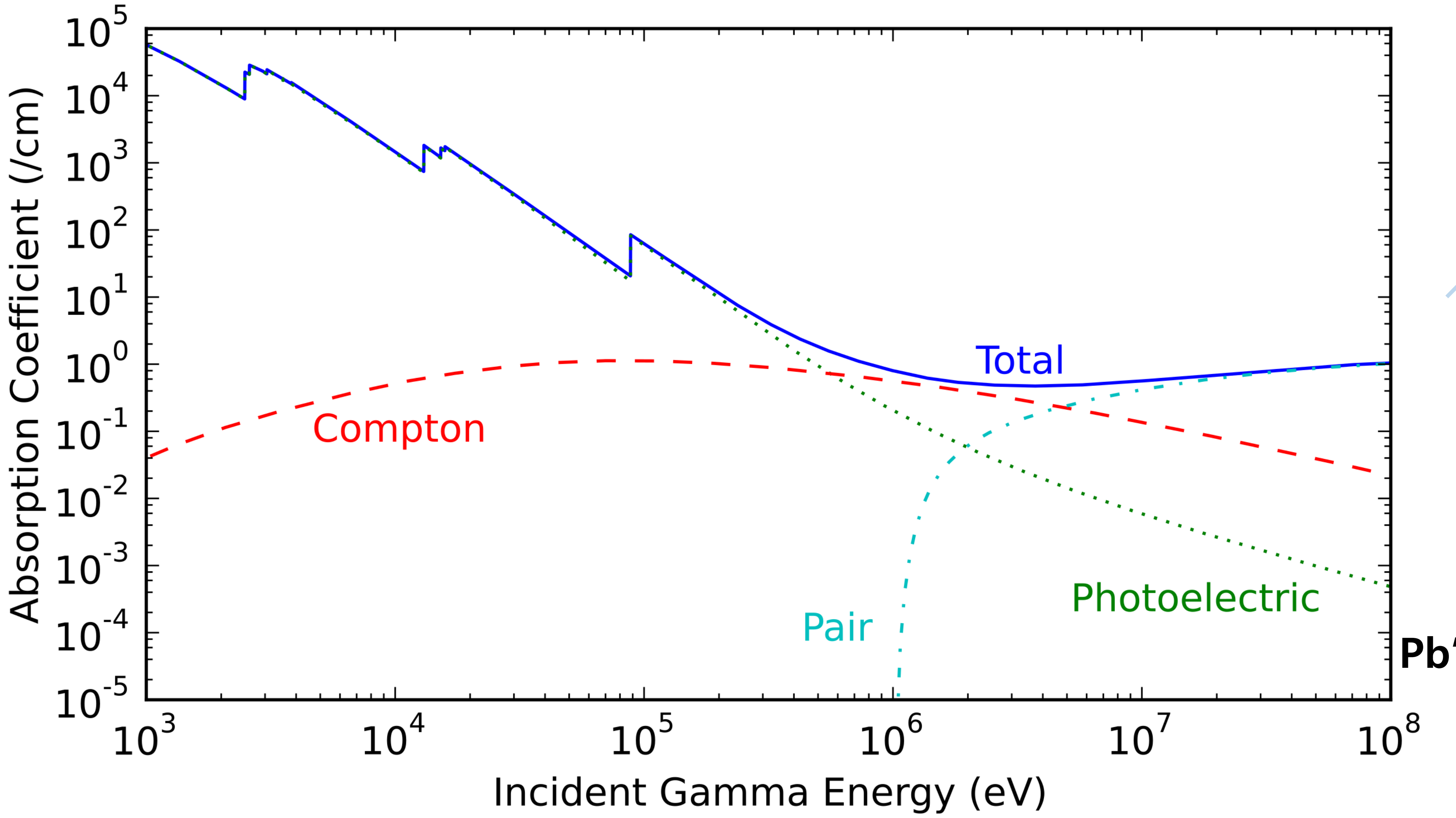


Gamma lay attenuation process



Attentuation length result for linear alkylbenzene

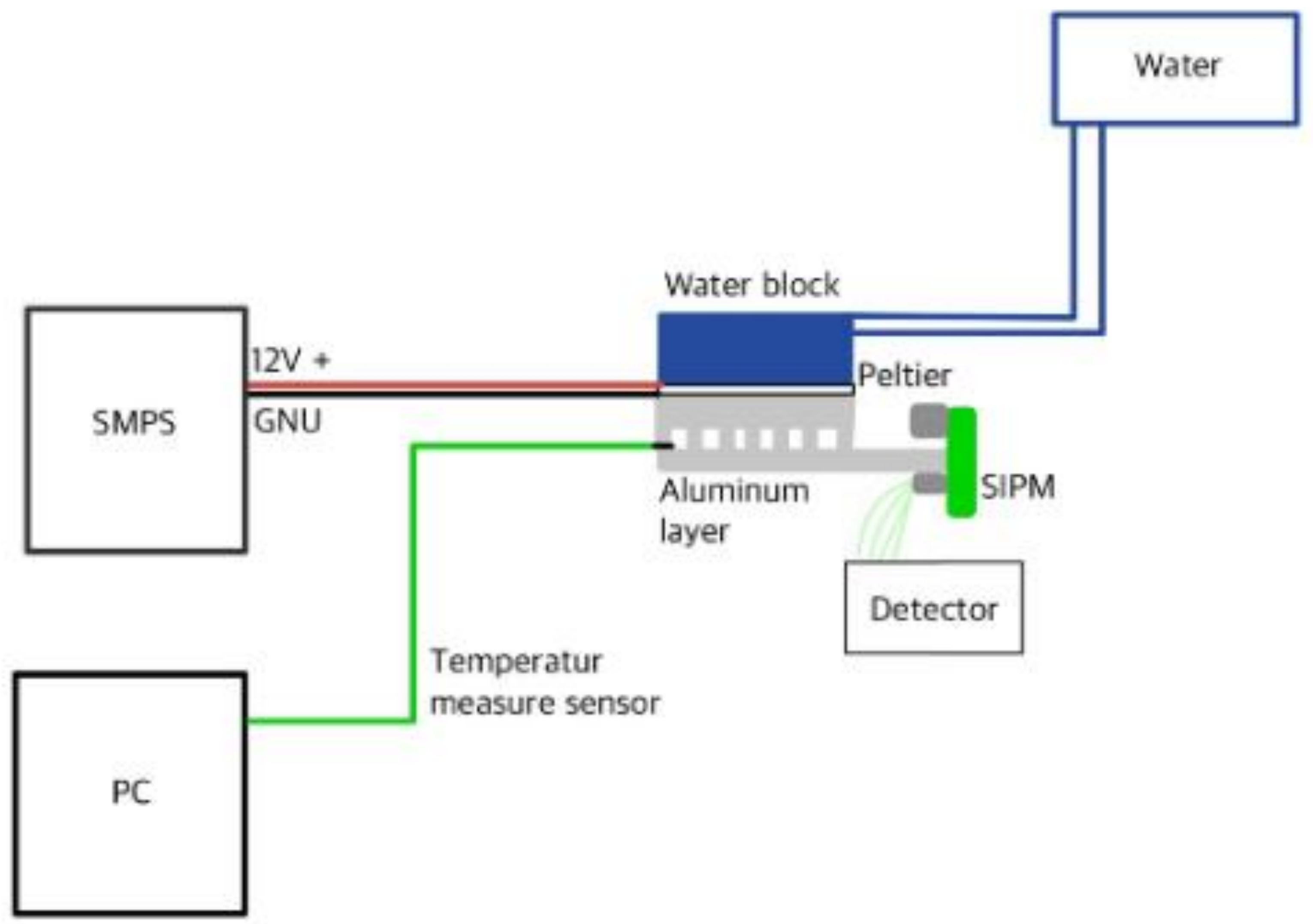
Attentuation length is proportional to
1 / attenuation coefficient

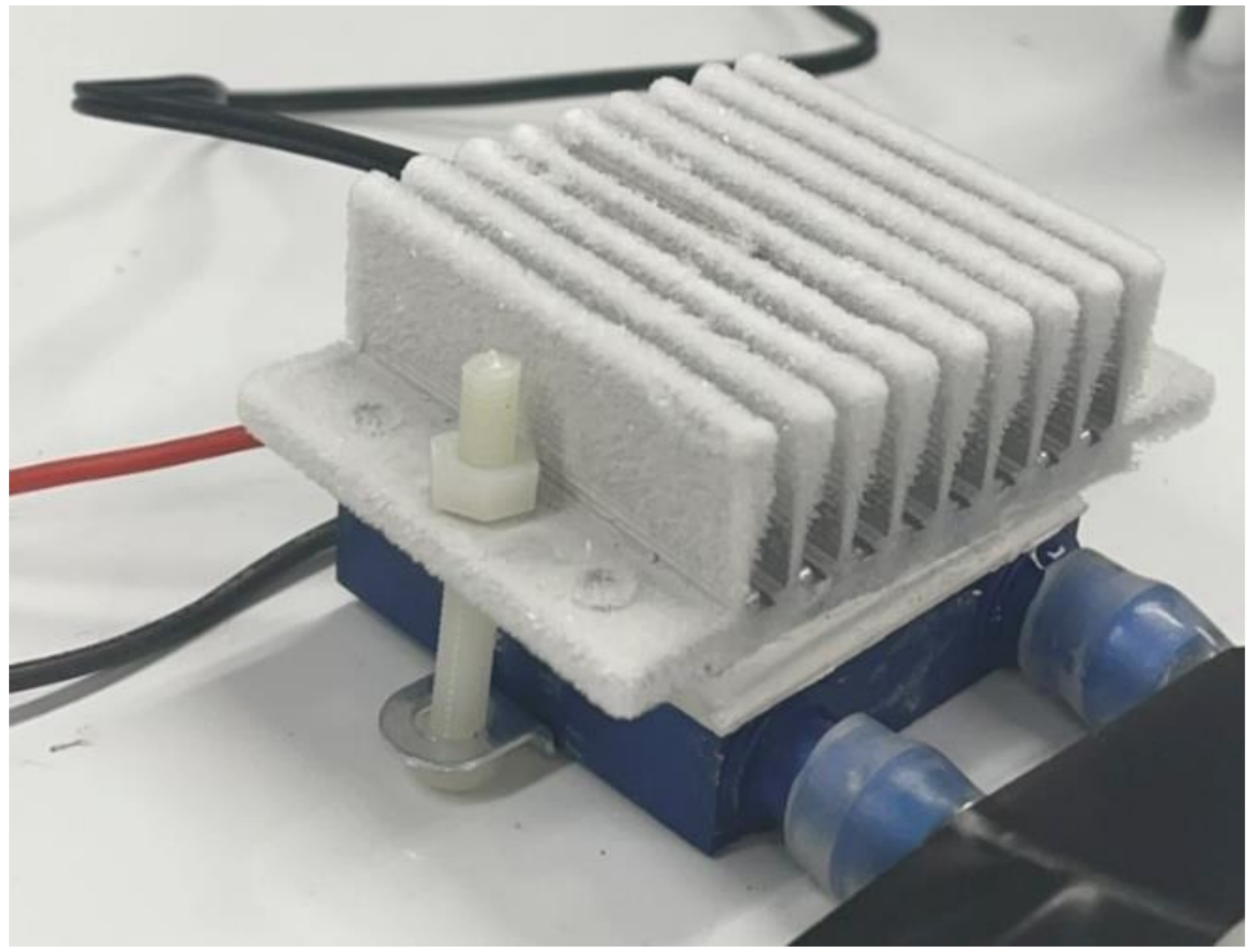


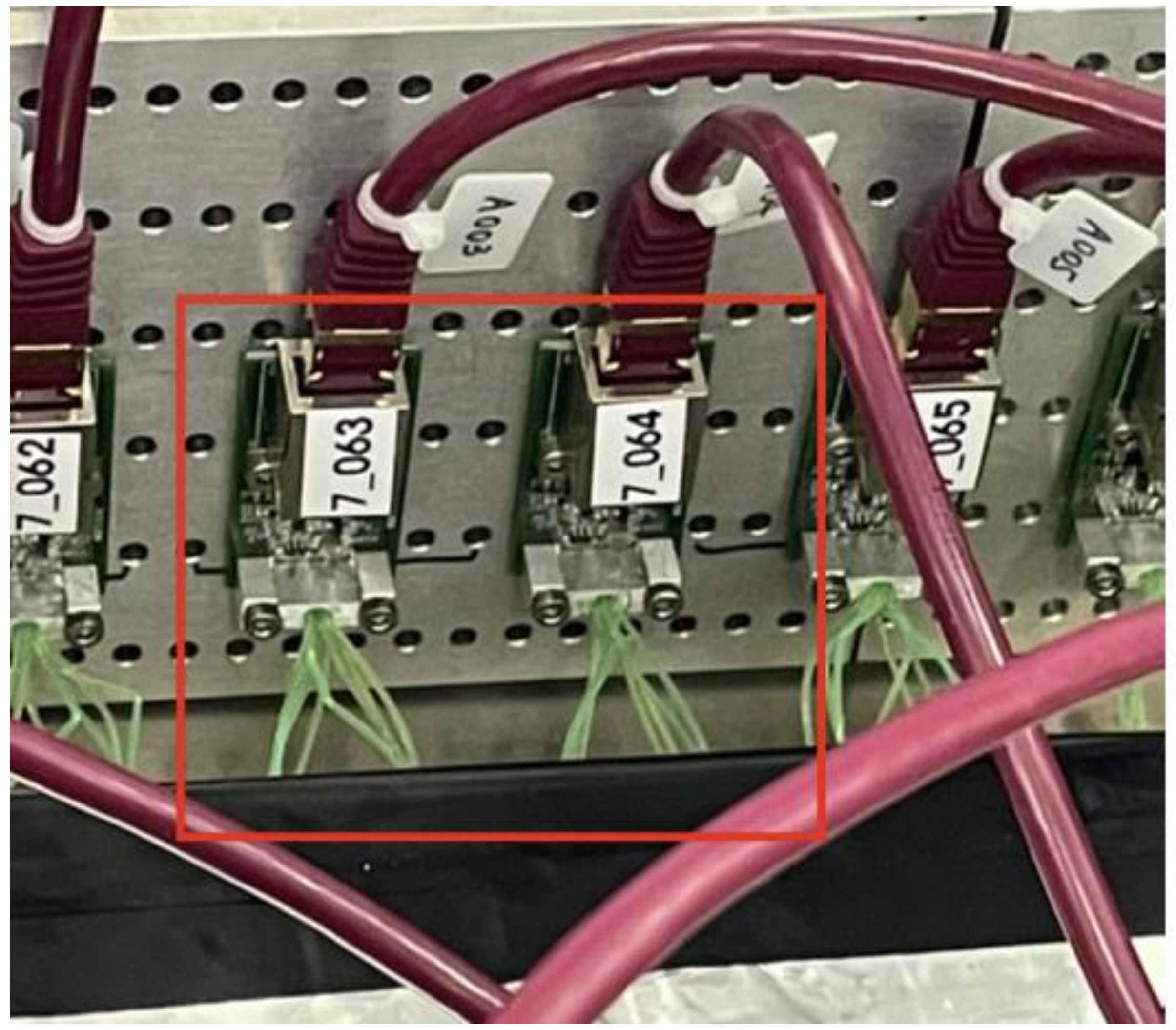
Pb's Attentuation coefficient for length calculation

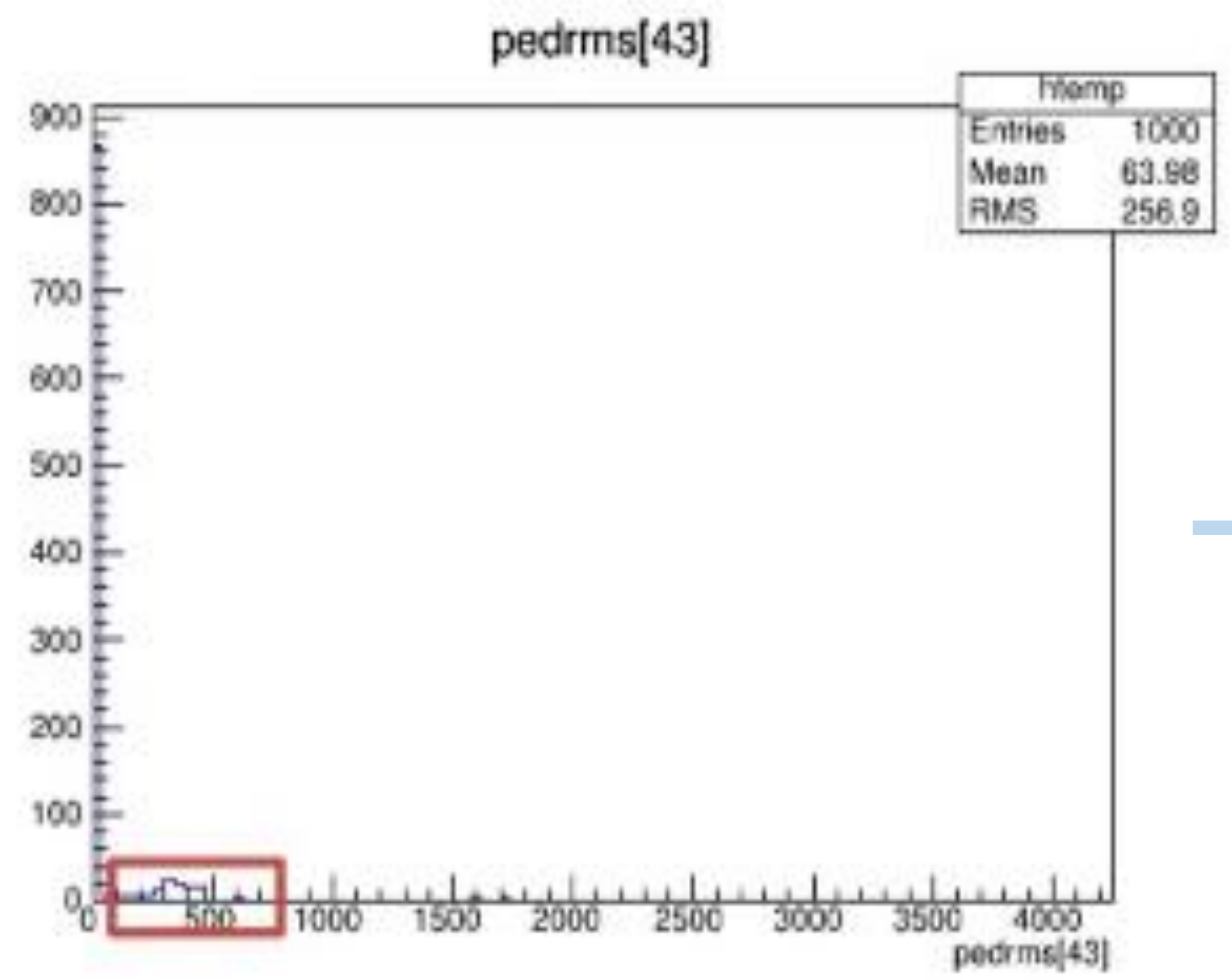
Research in Physics (required major course)
A study on performance about particle detector using Peltier Module

1. SiPM performance improvement

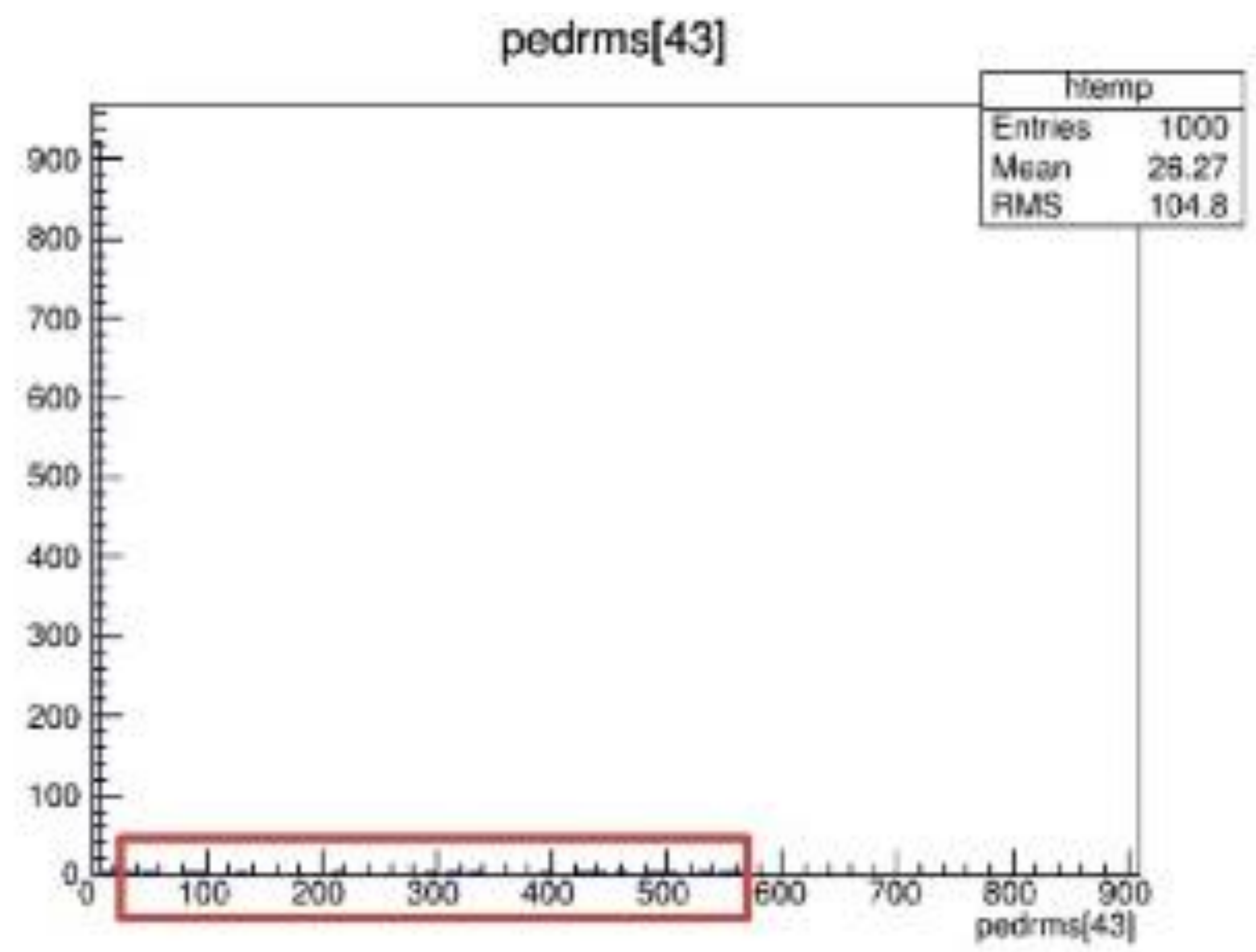




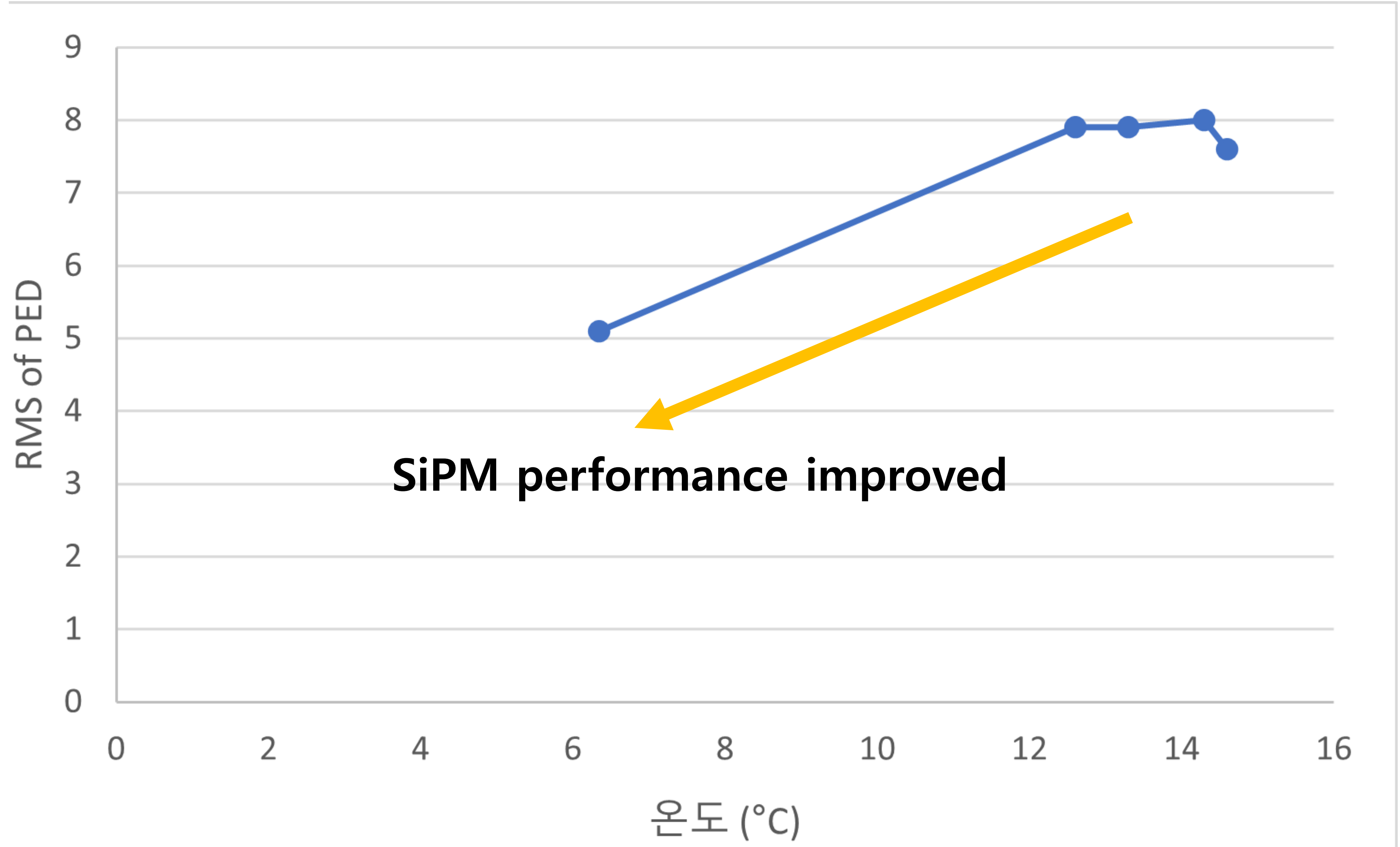




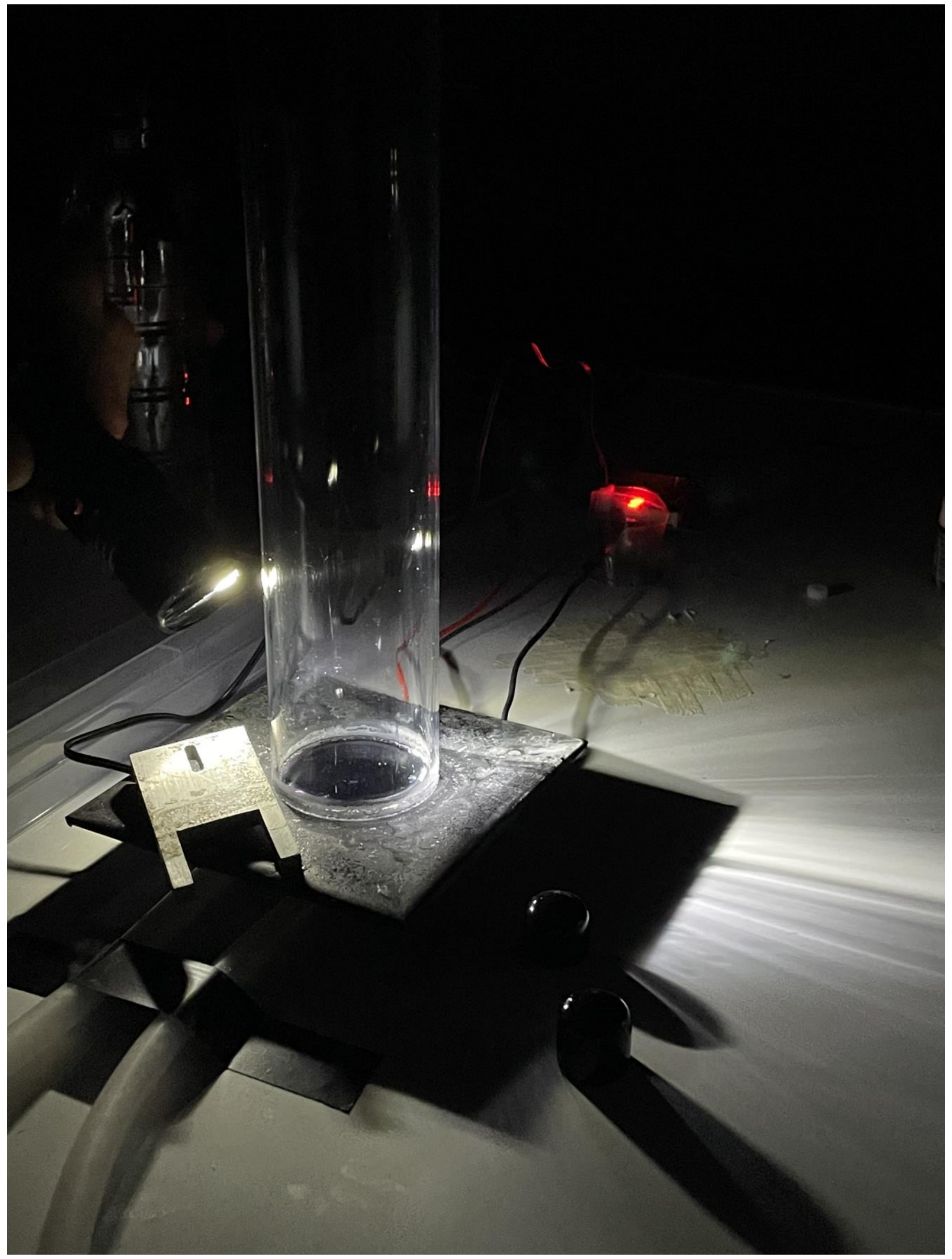
SiPM performance at 13.3°C



SiPM performance at 6.5°C



2. Willson's Cloud Chamber



Cloud chamber experiment

Alpha particle detection

Beta particle detection

Summary

Attenuation length Common function develop

- We can get total attenuation length by importing the calculation code with the list of attenuation coefficient of mat erial.
- For the further study, we are making the common code to fit several type of gragh with fitting model and methods. (chi-square, maximum likelihood)

A study on performance about particle detector using Peltier Module

- Peltier Module can reduce the noise of sensor signal by lowering the temperature of sensor which can improve the performance of SiPM
- it can be applied to other studies (Noise can occur in any signal)