Data analysis for reduction of ^{208}Tl background events in CANDLES system

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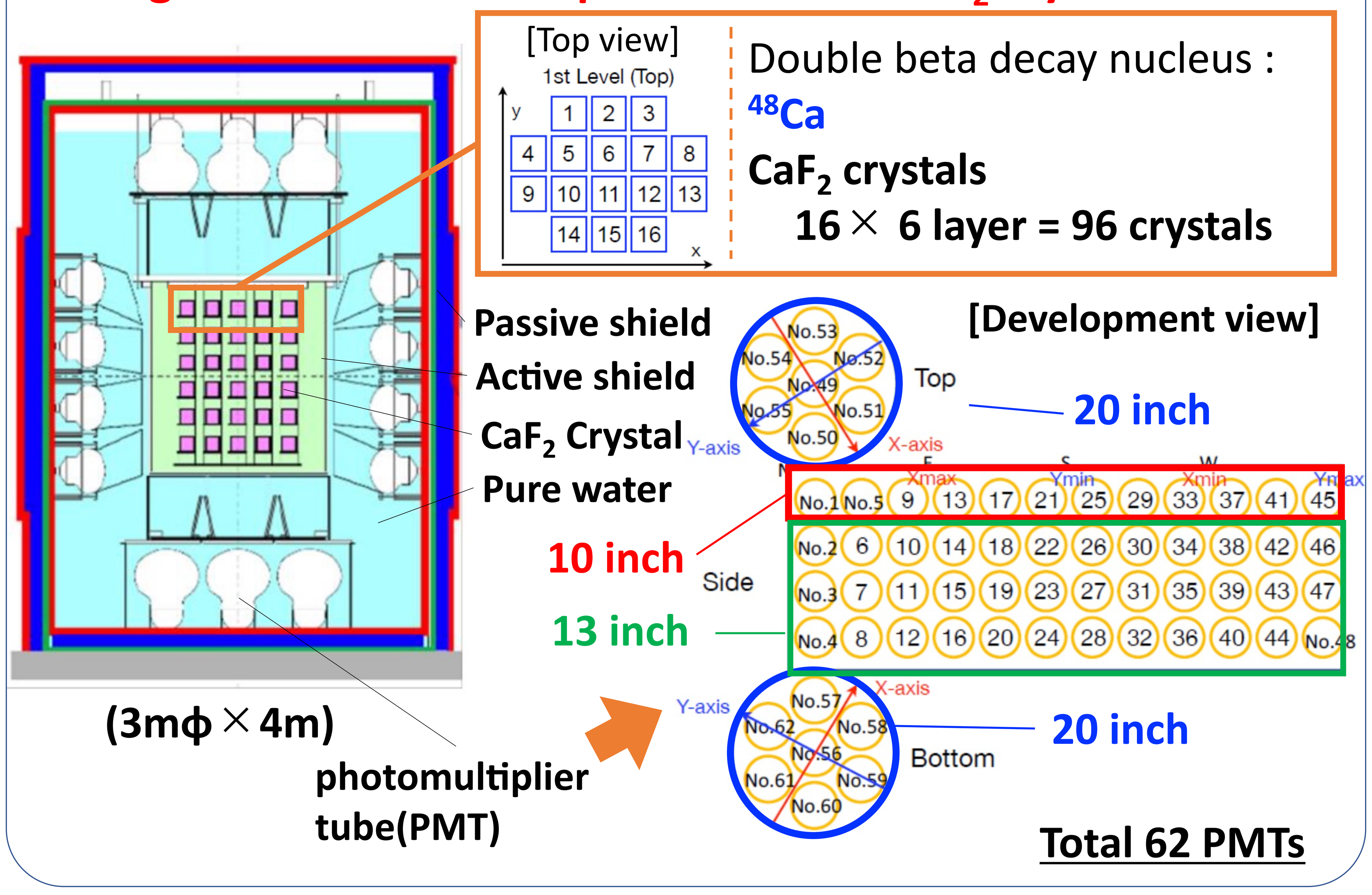
1.Introduction

It has been more than 60 years since neutrinos were discovered. However, the origin of the masses of neutrinos is yet unknown. One of the promising scenarios is that neutrinos have **Majorana masses**. Observation of neutrino-less double-beta decay (0νββ) is a powerful method for validating the scenario. If 0νββ decay is observed, it will not only promote better our understanding of neutrinos but will also play major role as a key to solve the mystery of why the current universe is composed entirely of matter.

2.Experimental set up

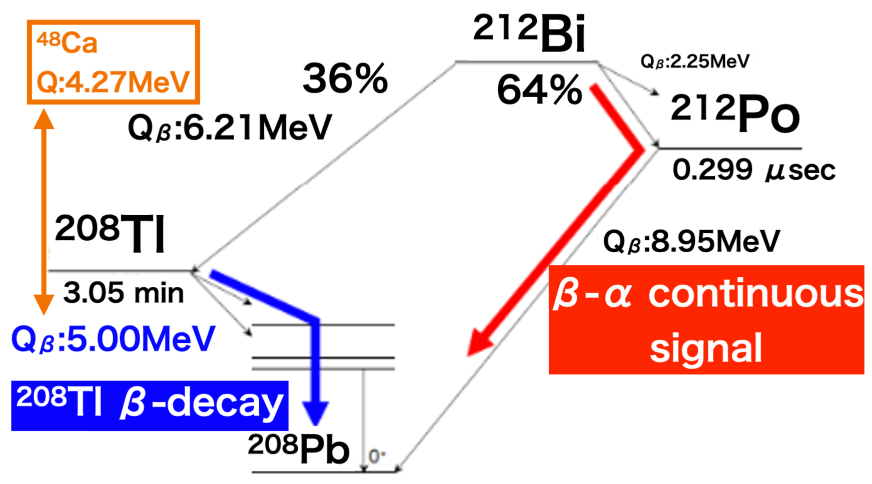
CANDLES system is installed in the Kamioka underground laboratory. We can reduce backgrounds from outside with various shields.

➡Originate from ^{232}Th impurities within CaF_2 crystal.

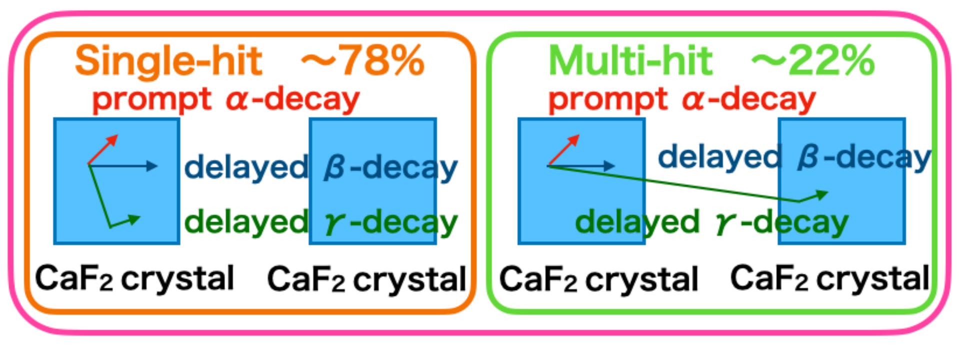


3.Reduction of background events

The remaining background is **^{208}Tl decay events** in the CaF_2 crystals, which is above Q-value of 0νββ decay of ^{48}Ca. In addition, γ rays from ^{208}Tl decay can drop energy in neighboring crystals (Multi-hit). We want to remove these backgrounds to realize purer measurements.

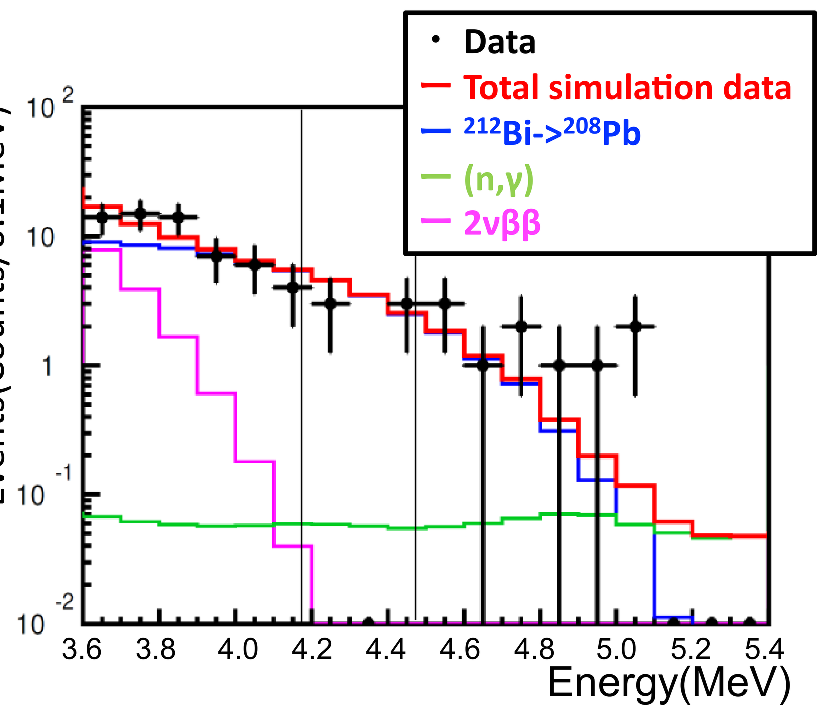


[^{212}Bi decay chain]



[Diagrams of ^{208}Tl decay events]

In previous analysis, we reduce ^{208}Tl background of single-crystal hit (Single-hit) events. However, there are also 22% multi-hit events for simulation, which can't be ignored.



[Backgrounds simulation]

Reference : Phys. Lett. D 103,092008 (2021)

The right figure shows how big the ^{208}Tl decay events are for 0νββ of ^{48}Ca.

4.Analysis method

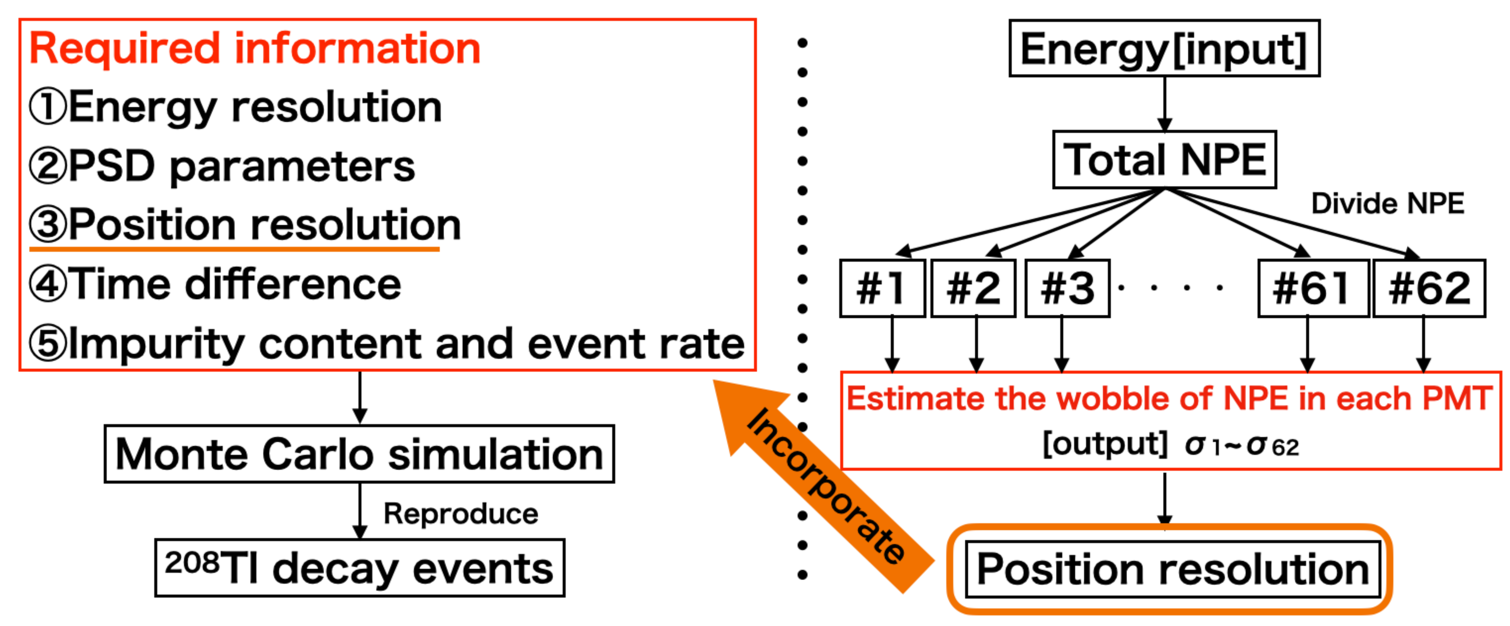
To reduce the ^{208}Tl background including multi-crystal hit(Multi-hit) events, we need to reproduce the energy spectrum and position distribution data of ^{208}Tl decay with Monte Carlo simulations. For that, we have to know **the position resolution.** We use sequential α-decays (^{220}Rn->^{216}Po[$T_{1/2}$ = 145ms]->^{212}Pb) of ^{220}Rn in the CaF_2 crystals to get it.

[^{220}Rn sequential α-decays]

Prompt and delayed α-decays **always** occur at **the same location** in the CaF_2crystals.

①Get **position resolution except the crystal size** from position difference between prompt and delayed
②Get observed crystal size data from fitting by using ①position resolution
③Get **the number of photoelectron (NPE) distribution** (Single-hit)
④Get the fluctuation of NPE in each PMT
⑤Estimate the position resolution following the right diagram

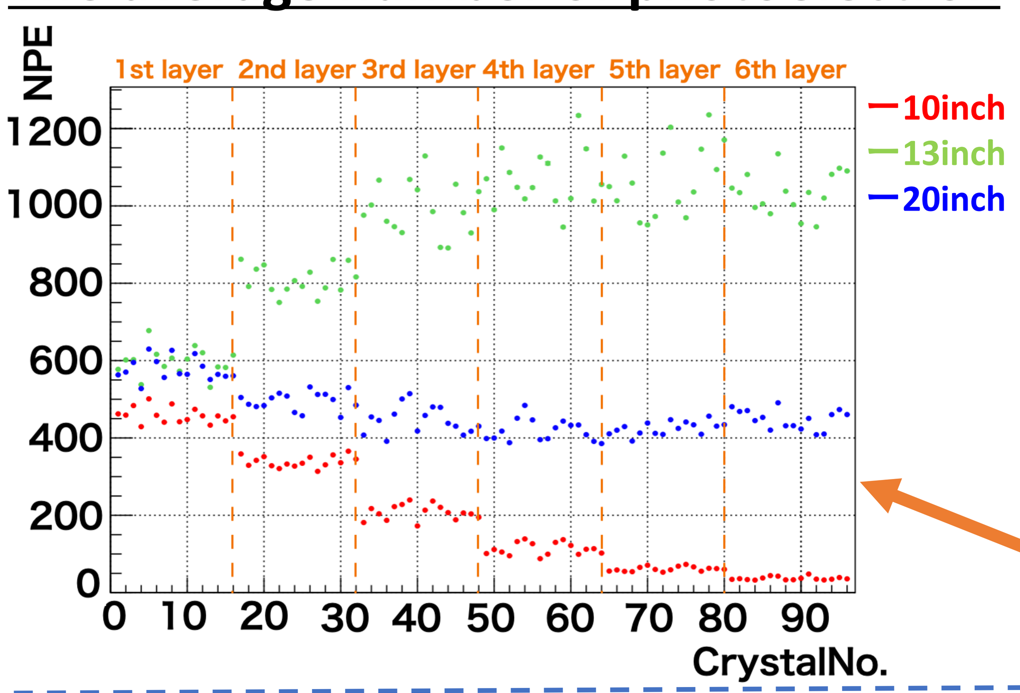
Diagram for estimation of position resolution

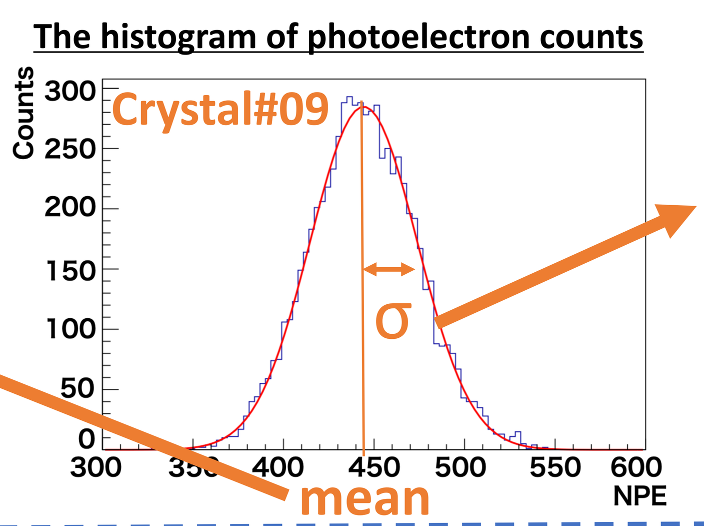


5.Results

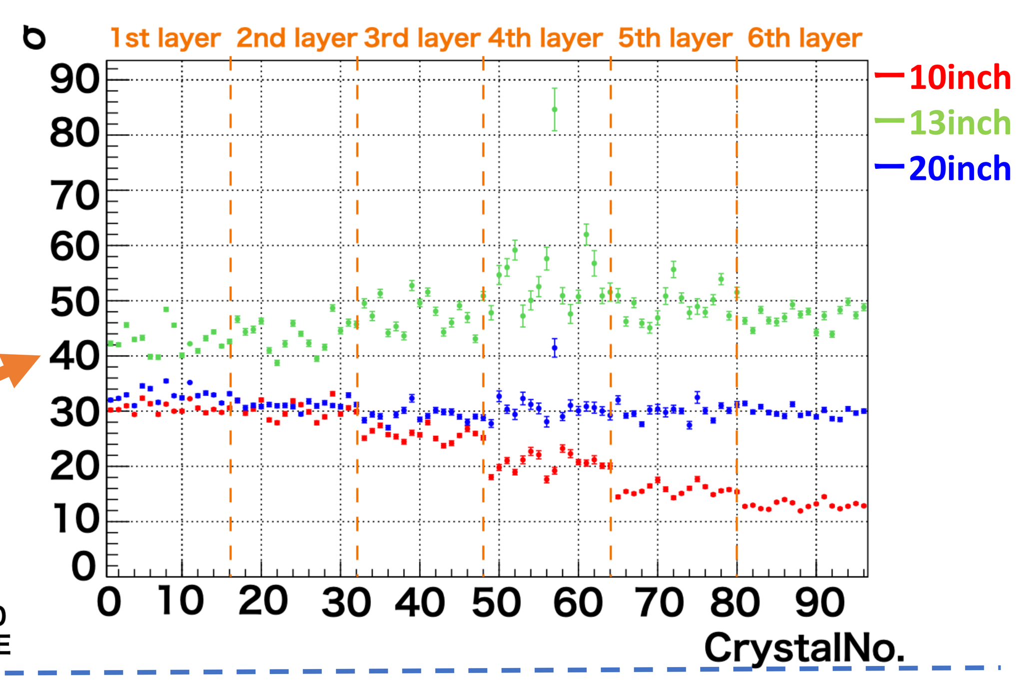
The following figures show the NPE distribution and its fluctuations in the analysis of ^{220}Rn decay.

The average number of photoelectron



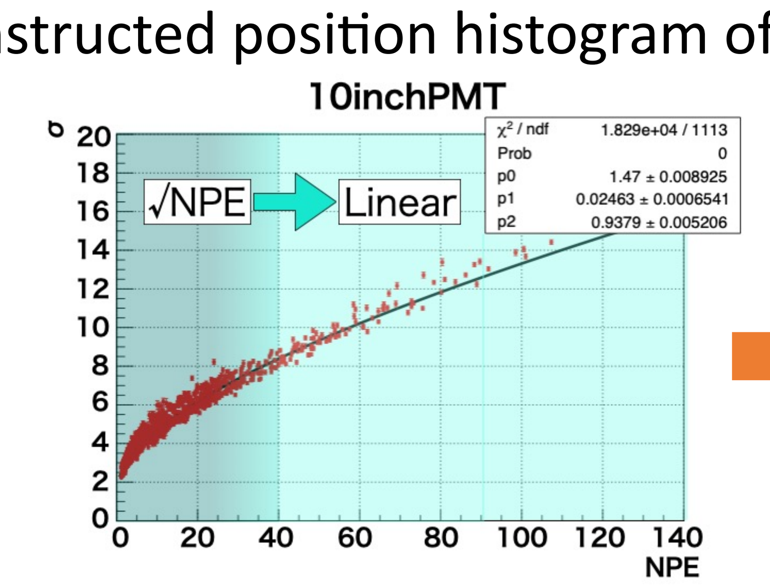


The fluctuations in average NPE

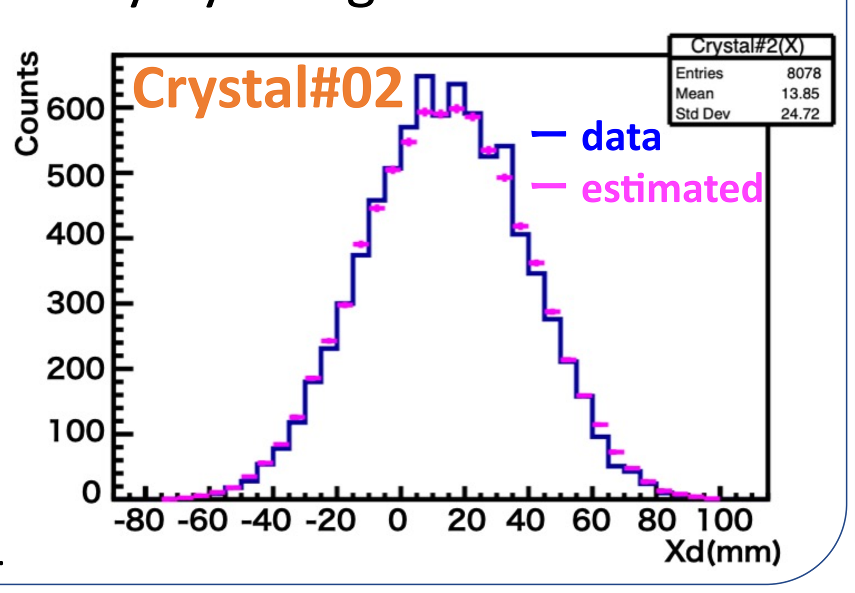


The following figure shows a reconstructed position histogram of ^{216}Po decay by using the NPE distribution of ^{220}Rn decay.

I clarified the correspondence between NPE and its fluctuation and created functions that show the correspondence for each PMT size. I could reproduce the data well for ^{216}Po decay by using this functions.



↑ This figure is a function to estimate the fluctuation of NPE.



6.Summary

・I clarified **the correspondence between NPE and its fluctuation** in CANDLES.

・I obtained **the position resolution** by using ^{220}Rn sequential α-decays.

The above contents obtained by the present analysis enable **accurate estimation of position**.

(Let you know the pulse shape discrimination analysis, please look at Yoshioka's poster.)

[Future plan]

In order to further reduce ^{208}Tl background, I incorporate this NPE distribution and position information into Monte Carlo simulation and reproduce the energy spectrum and position distribution of ^{208}Tl decays.