The optimization of neutron veto counter in XENONnT, the highly sensitive dark matter research experiment

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summary

about XENONnT experiment

- introduction
- neutron veto counter and reflectors

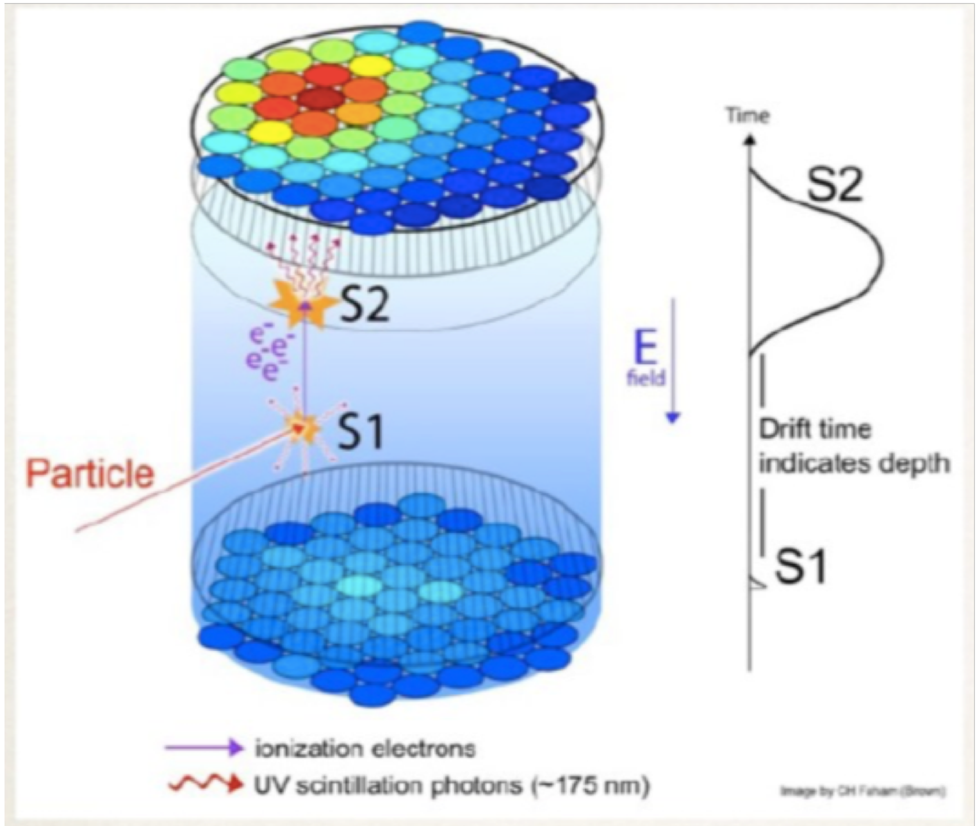
comparison of reflectivity

- experimental device we made
- analysis and results

homework and next plan

- improvements on analysis
- check reproducibility
- connection with other studies (to achieve optimization)

XENONnT experiment（overall）



・aim for direct detection of Weakly Interacting Massive Particle (WIMP), one of the convincing candidates of the dark matter particles

・dual-phase liquid Xe detector

・use the collision reaction of 10-1000 GeV WIMP and Xe nucleus

・sensitive to scattering cross section ~10^{-48} cm^2

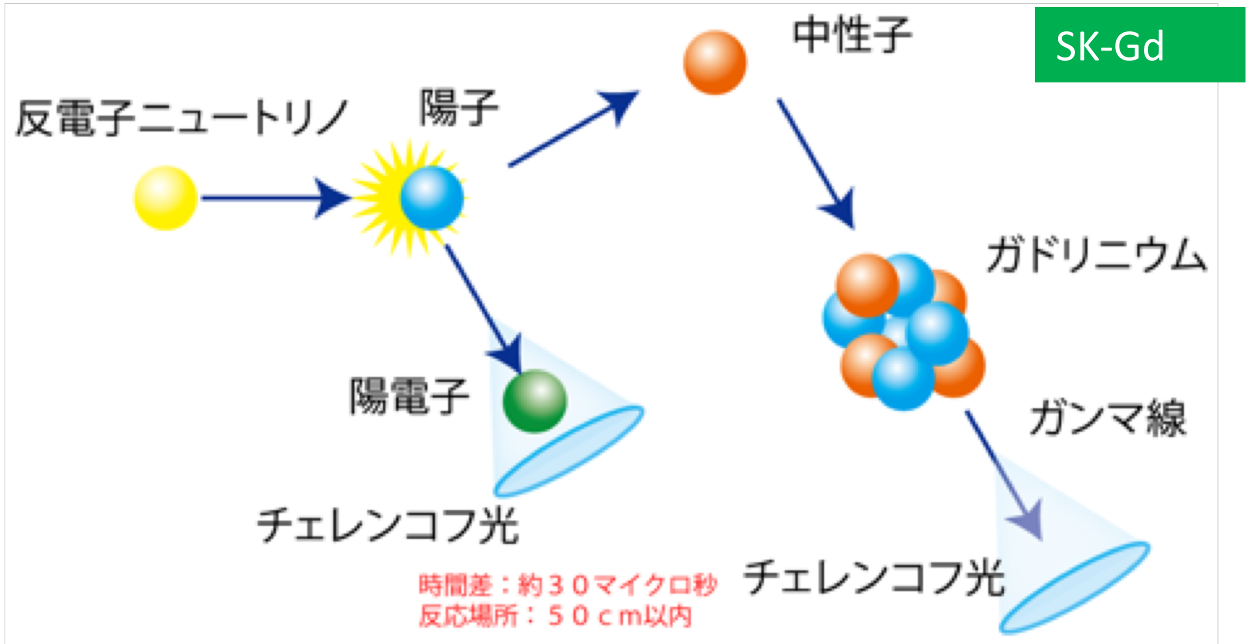
・collaborators from Japan include Nagoya university, Kobe university, and U-Tokyo

XENONnT experiment（neutron veto counter）

・any convinced positive signal from WIMP has never been observed, but they are hoped to be detected with XENONnT detector
・this detector can distinguish “signal from Xe nuclear recoil caused by WIMP” and other background

・cannot distinguish “signal from Xe nuclear recoil caused by neutron”
(neutron is produced by natural decay of U and Th)
background rate is 1.8 events/yr in ~4 t fiducial volume
→ about 9 events in run time (about 5 years)

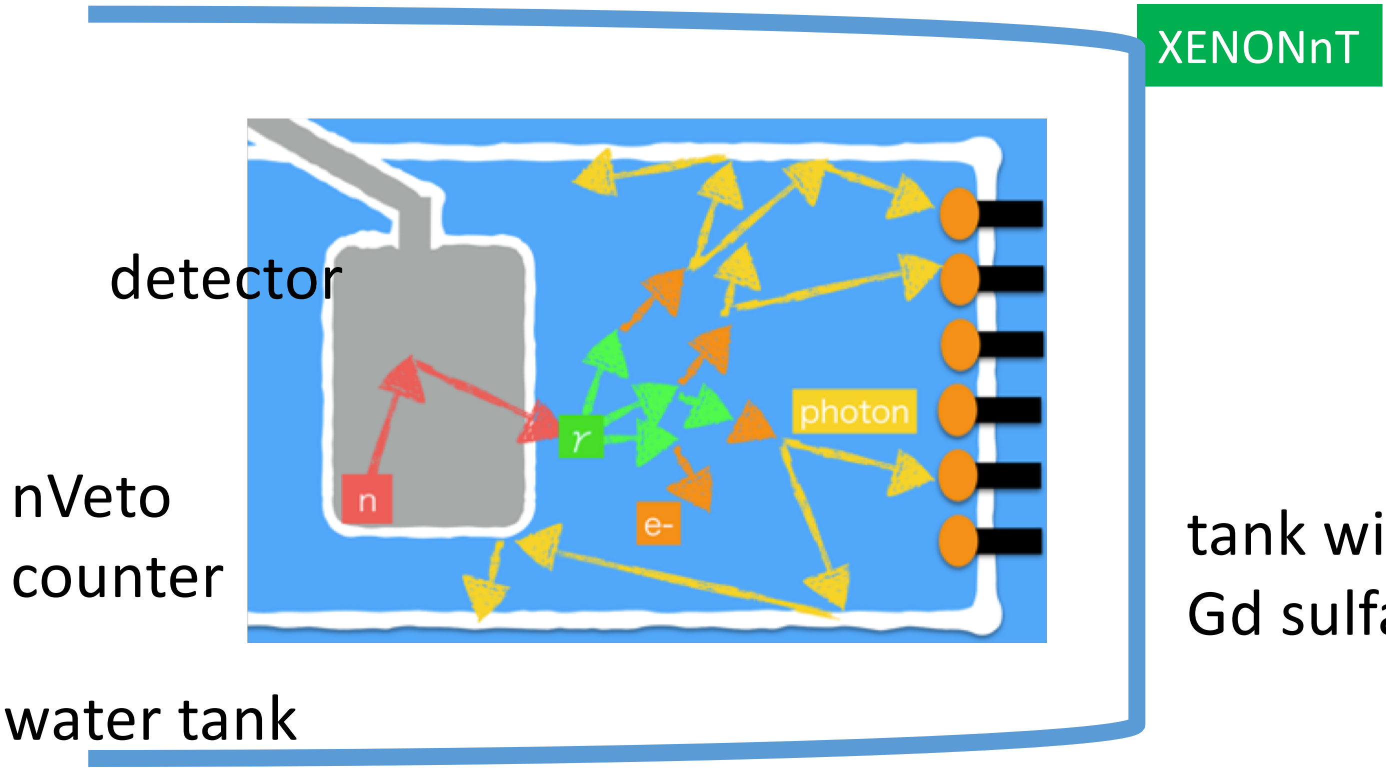
introduce the method in SK to XENONnT



neutron capture by Gd
(developed at
Kamioka Observatory)

particles recoiled by Xe will cross outer detector
WIMP goes through without reaction, but neutron reacts with Gd ions and emit signal
→ WIMP and neutron can be separated whether signal can be observed from outer detector

XENONnT experiment（neutron veto counter）



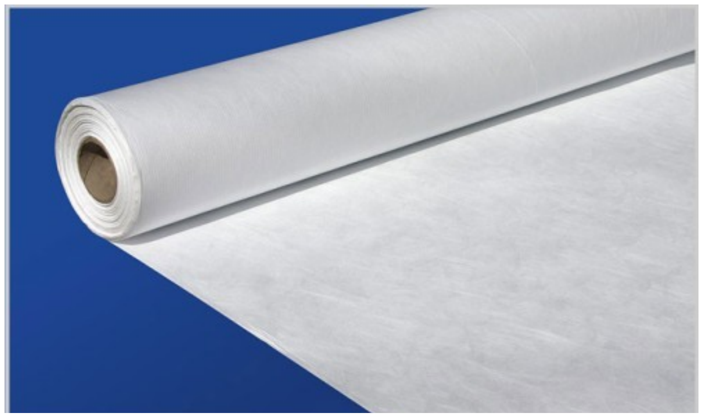
tank will be filled with
Gd sulfate loaded water

Emitted Cherenkov photons are reflected several times in outer detector before observed with PMT
→ reflector with the best reflectivity is required to catch the signal definitely

motivation of the comparison of reflectivity in water

to choose the reflector which gives the best reflectivity in "water"
reflectivity in "air" is already measured, but it may change in water due to some reason, for example,
・difference in refractive index
・reflectors absorb water

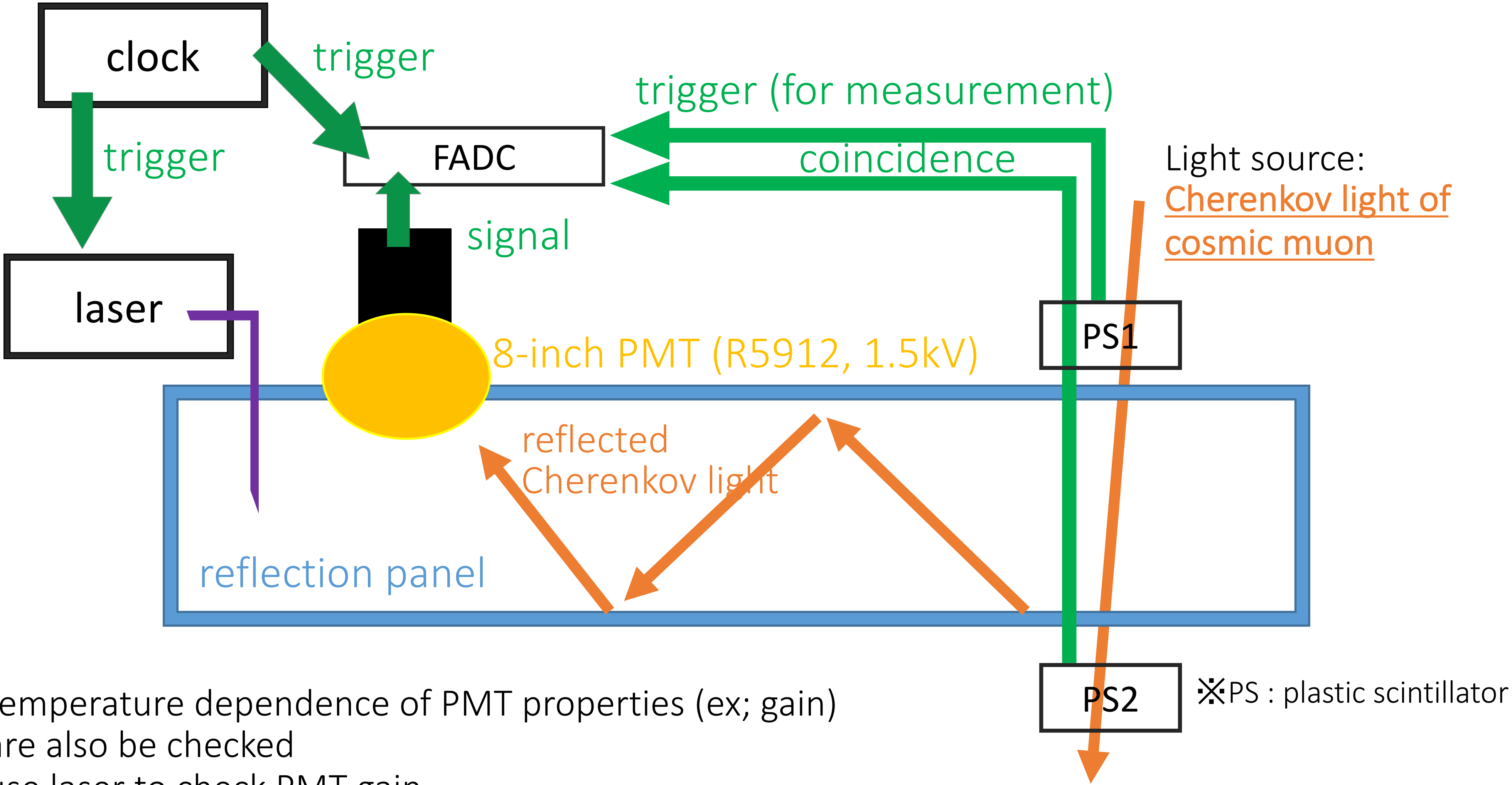
candidates of reflectors :
・tyvec (used in outer detector of SuperK)
・Goretex hyper sheet gasket
(have good reflectivity in the air, results are shown in backup)



tyvec 1082D

Goretex hyper sheet gasket 1.5mm

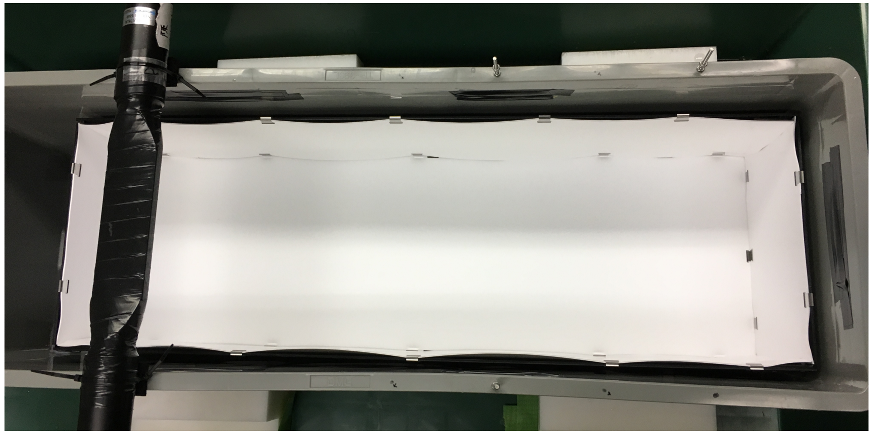
set-up of experimental device



temperature dependence of PMT properties (ex; gain)
are also be checked
use laser to check PMT gain

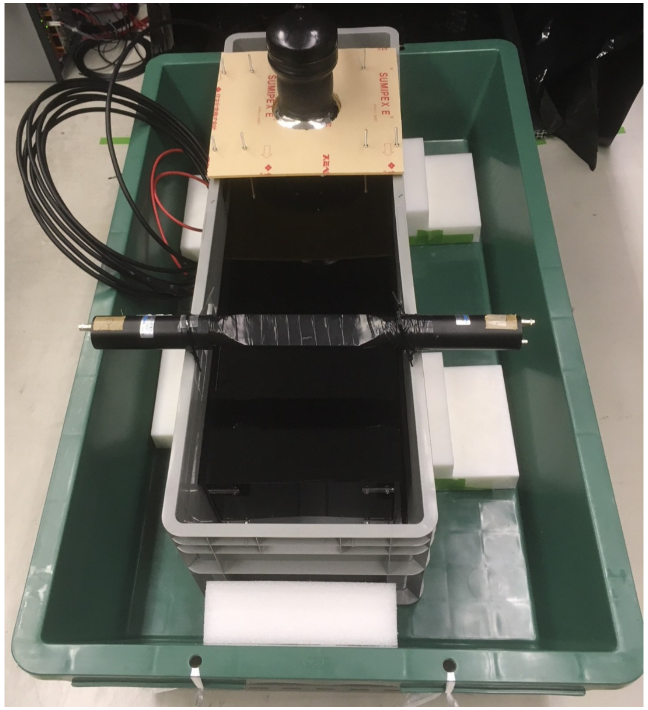
data taking
laser signal (1kHz clock, 10min) and cosmic muon event (with 1Hz clock, 1 hour)

set-up of experimental device



Gore hyper-sheet 1.5mm
another measurement was tyvec 1082D

overall device
(with black box)



overall device
(without black sheet)

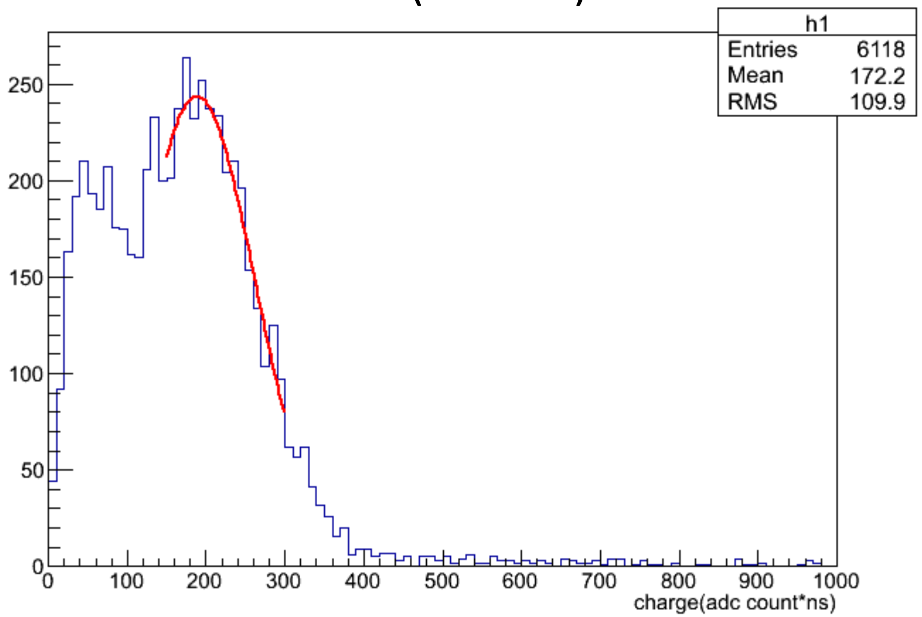
green container is for
avoiding water to
spill out

exit for signal cable

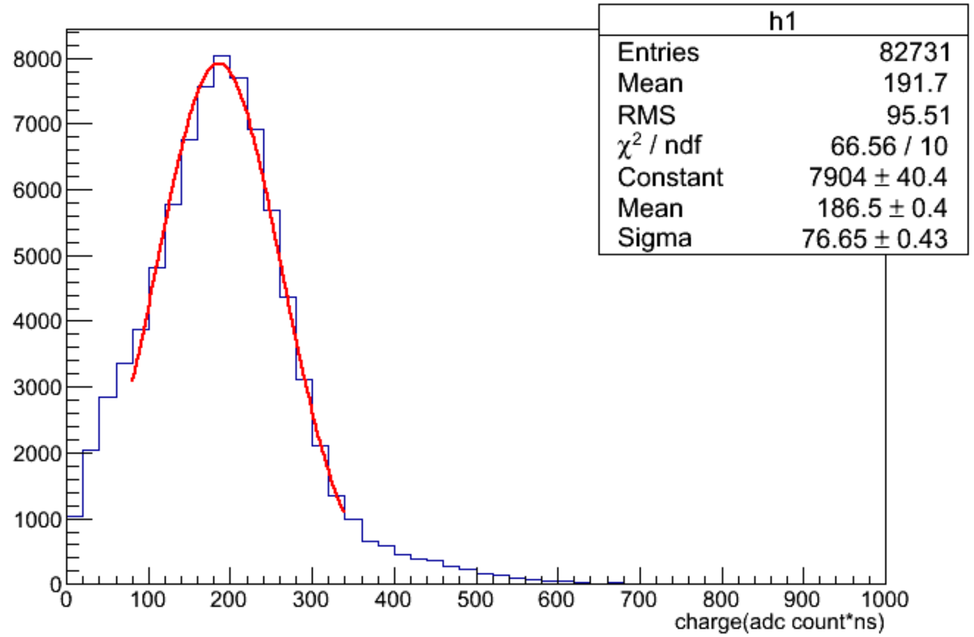
gain of PMT

to fit with Gaussian, large statistics is required
at first, we use dark pulse to see PMT gain, but the statistics was not enough, so we introduce laser to have more statistics

dark (run491)

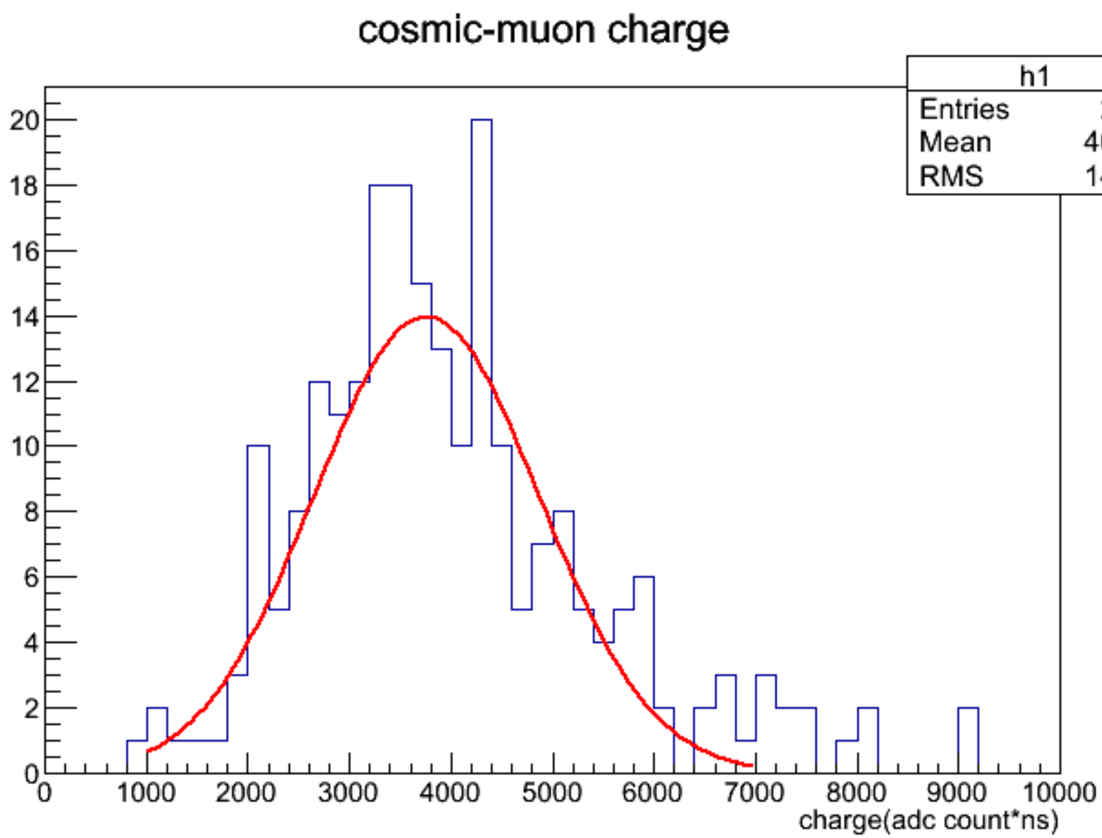


laser (run1646)



both of them are 10min measurement

typical charge distribution of cosmic muon event



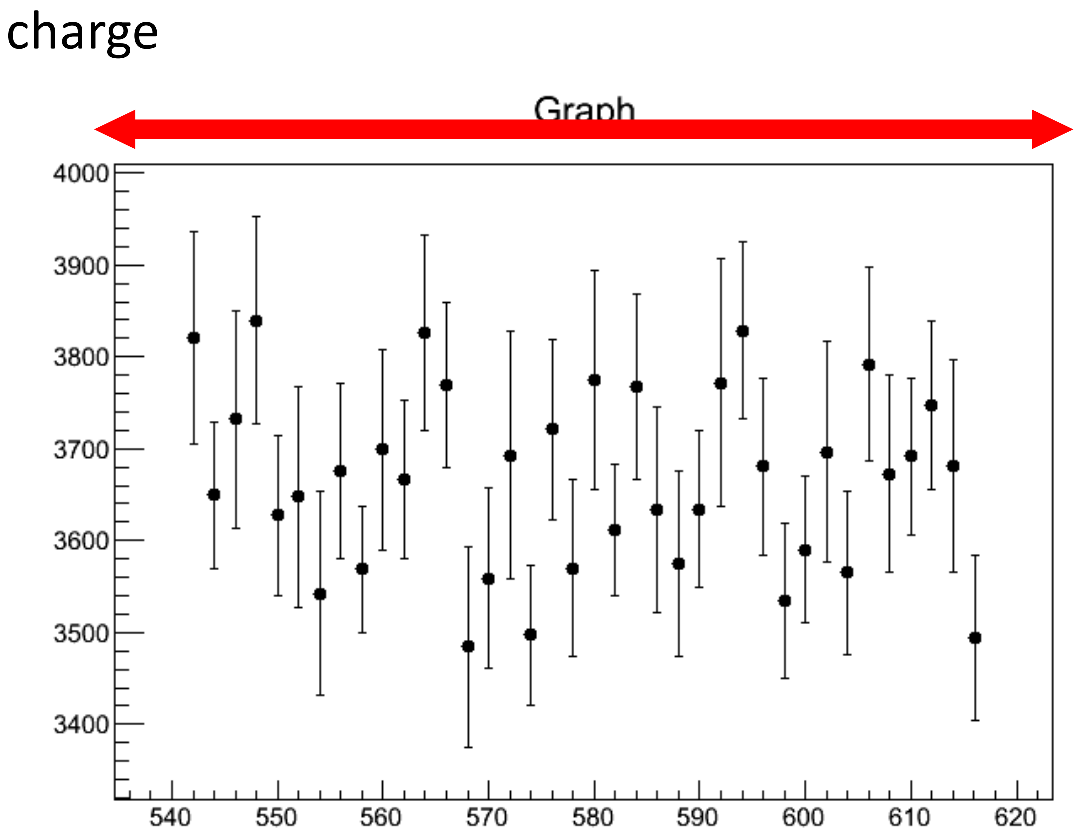
run546

reflector : tyvec 1082D

1pe～200(adc count*ns)

chi2 of this fitting
still have to be checked

run542-616 (tyvec 1082D, cosmic)



measurement about 2 days

1 point : 1 hour

※run618 was not well measured

run

2018.12.13 18:01

2018.12.15 13:21

water temperature

18.9°C

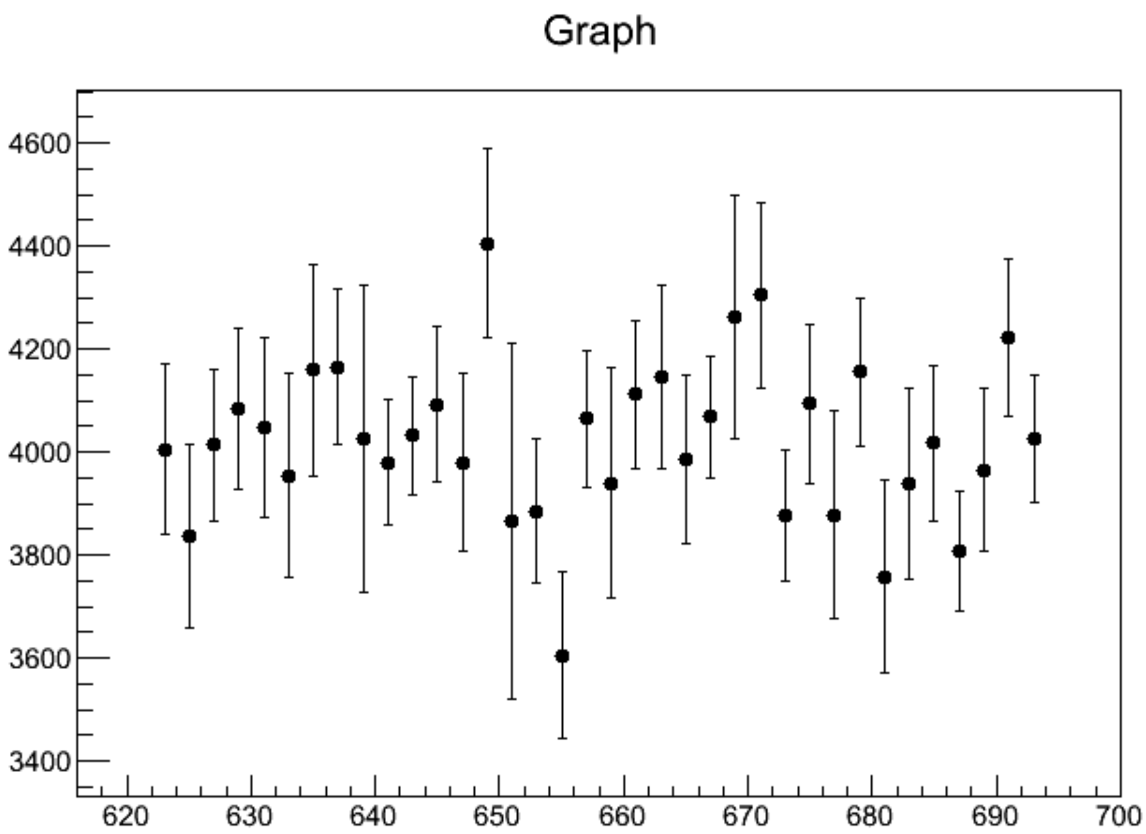
19.5°C

19.3°C

※temperature dependence of PMT gain is shown in backup

run623-693 (Goretex, cosmic)

charge



run

2018.12.15 19:13 2018.12.17 12:13

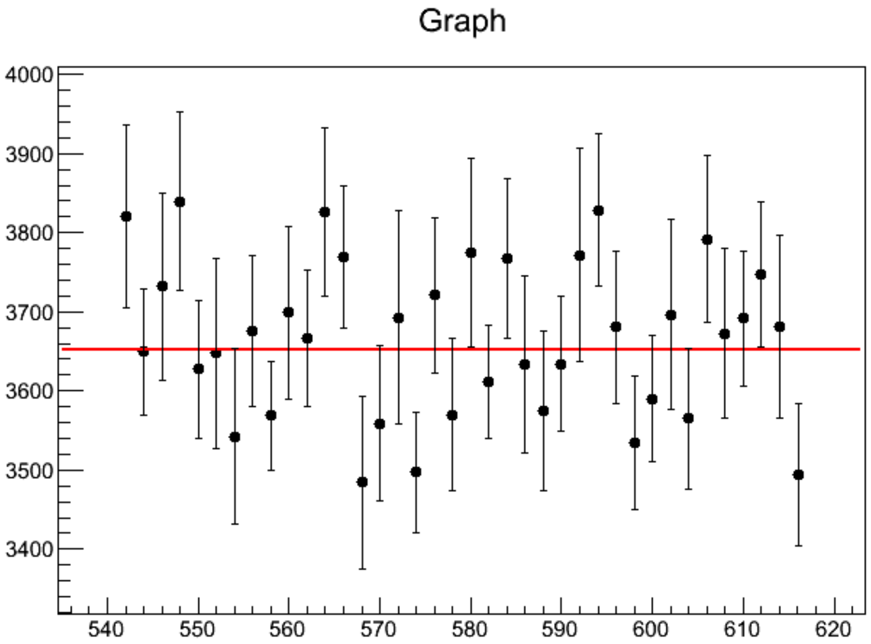
water temperature 14.9℃ 16.9℃ 18.5℃

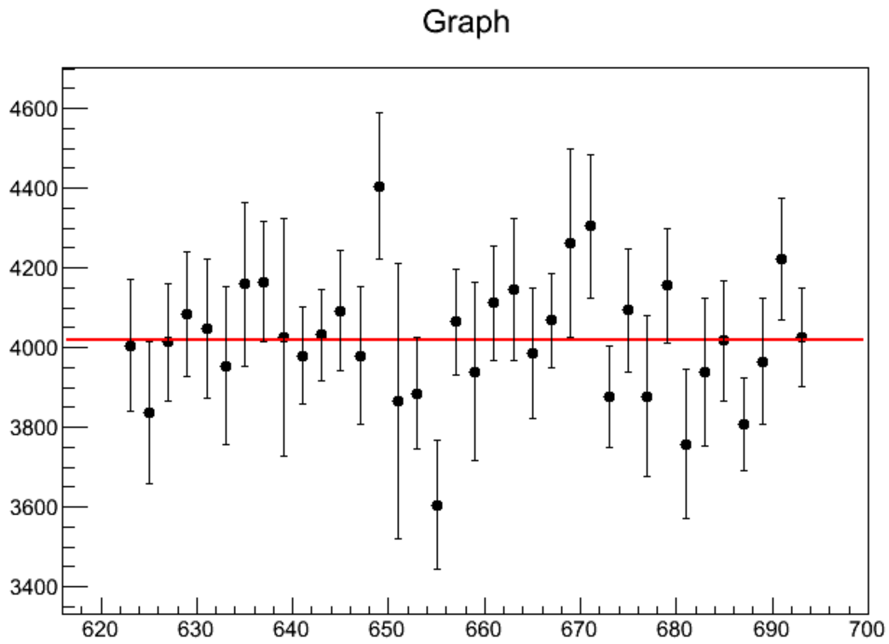
tyvec 1082D, cosmic muon event

Goretex 1.5mm, cosmic muon event

fit in constant

charge





run

Chi2 = 38.6227
NDf = 37
p0 = 3652.09 +/- 15.5712

Chi2 = 30.357
NDf = 35
p0 = 4017.59 +/- 26.2109

average charge is tyvec < Goretex
(about 10% difference)

future plan

by spring of 2019

・check reproducibility (ongoing)

・separate two effects of “the change of water quality” and “the change of reflectors”

・carry out the measurement with other reflectors (there are about 5 other candidates)

・select the best reflector and order it for construction

・design the best neutron veto counter

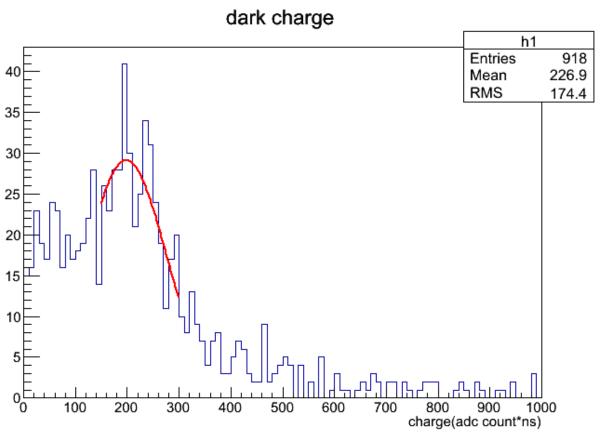
from June 2019

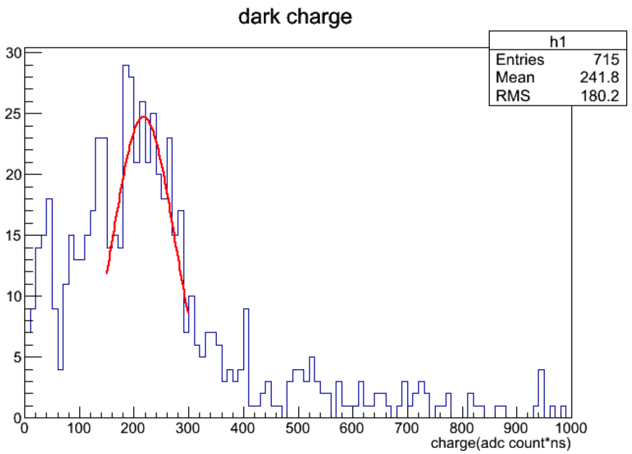
・join the construction of XENONnT detector

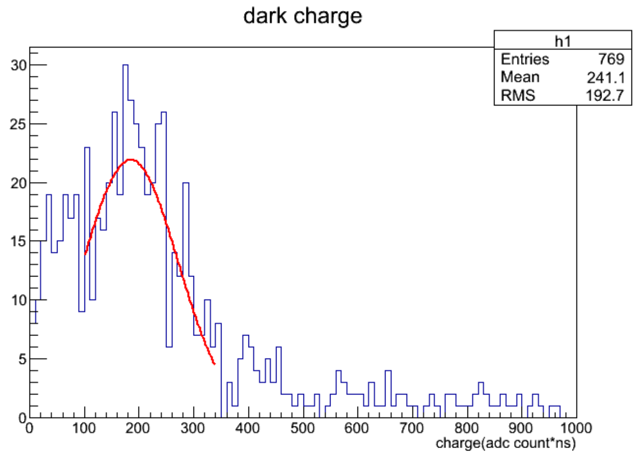
back up

confirmation of gain stability

typical 3 fitting results







no reliable fitting results so far on dark hit events

improvements

・iterative fitting including determination of fitting range

・appropriate binning

・using laser diode to have higher statistics

in this measurement, temperature changes about 4℃

・sensitivity of bi-alkali changes about -0.2%/K

→change in this measurement is under 1%

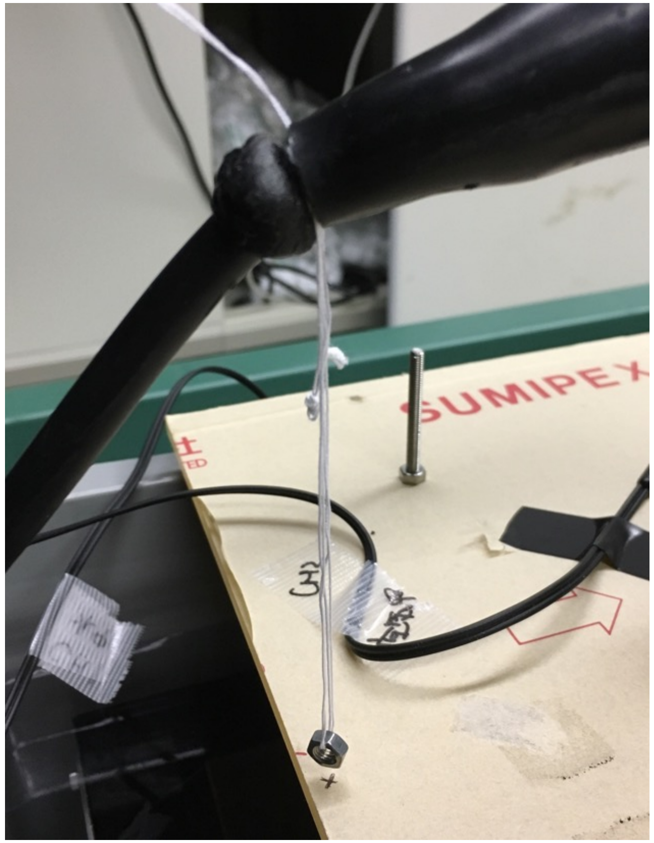
・gain changes about 1%/3℃

difference between tyvec and Goretex was about 10%, so it is not due to the changes of sensitivity or gain

set up (how to fix position)

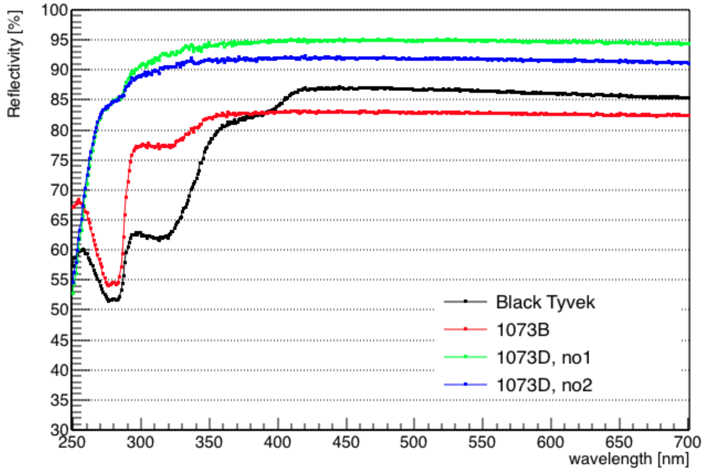
PE blocks to fix the
position of gray container

fix plastic scintillator
on the gray container

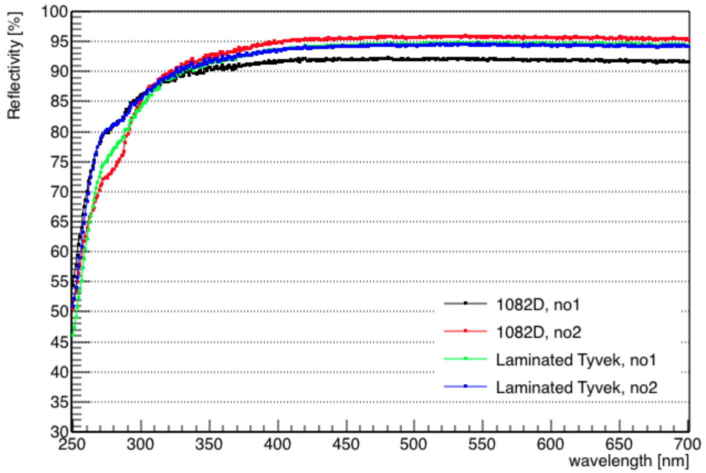


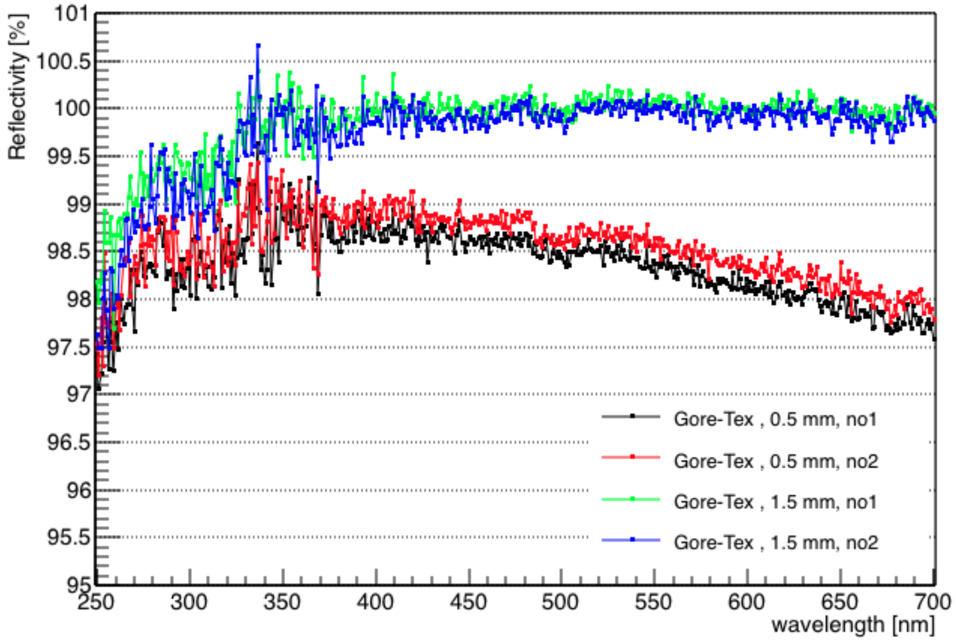
fix the angles of
8-inch PMT

reflectivity in the air (measured by Shingo Kazama)

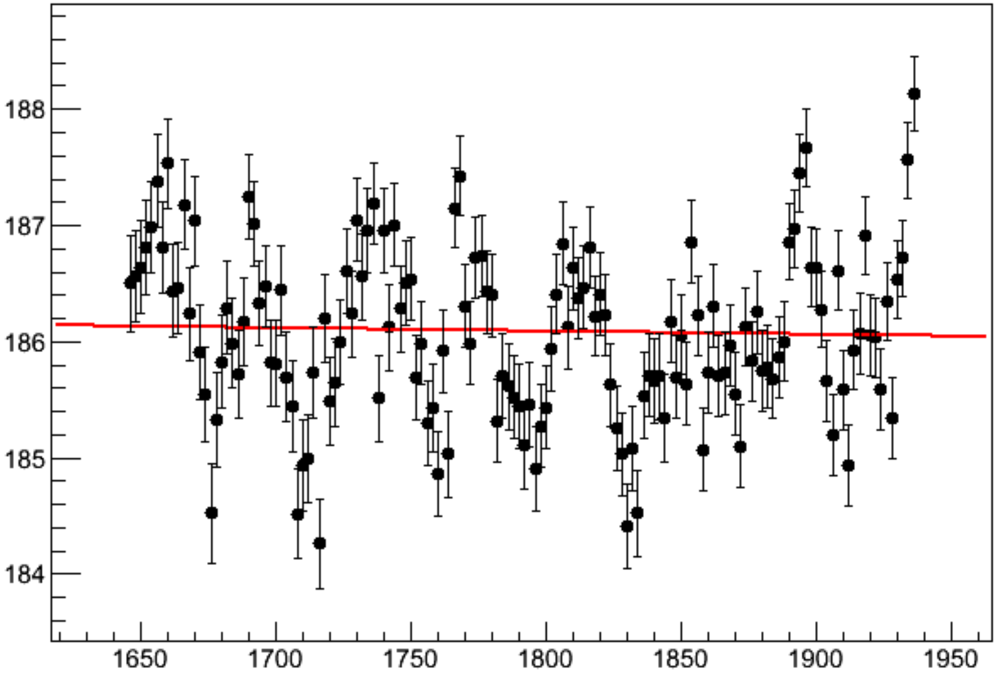


reflectivity difference
due to ununiformity

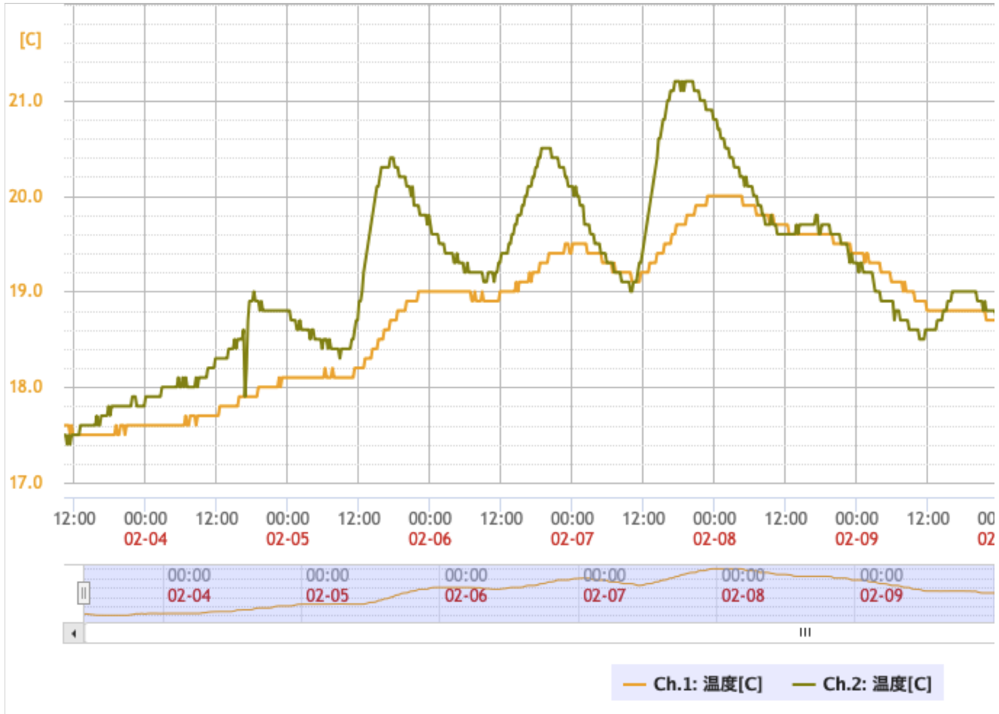




temperature dependence of PMT gain



PMT gain measured by laser pulse
have “wavy” time dependence

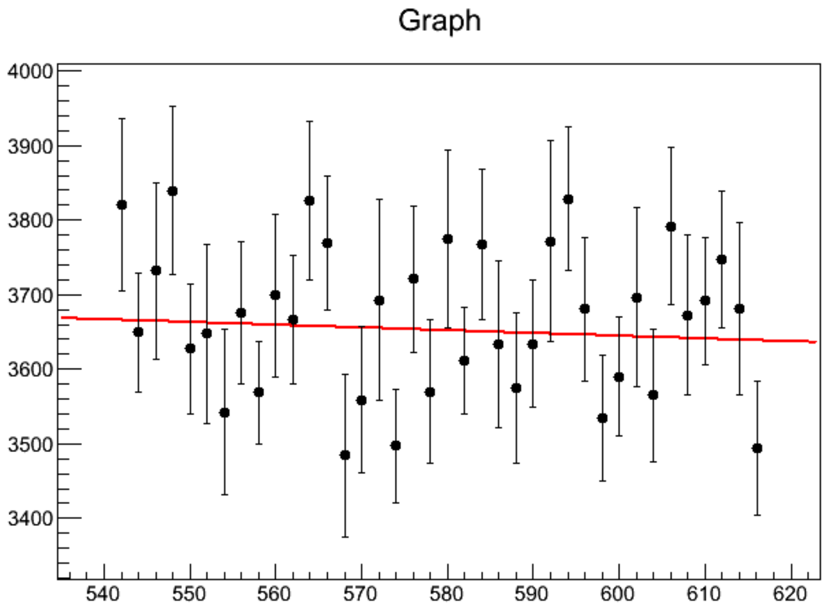


we think this is caused by temperature change
※two graphs are not the data of the same day

fit in primary function

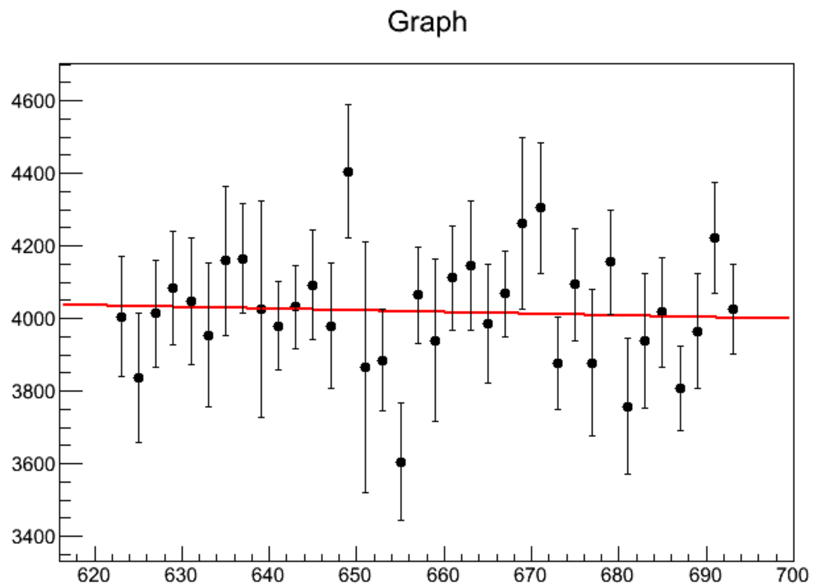
tyvec 1082D, cosmic muon event

charge



Chi2 = 38.3577
NDf = 36
slope = -0.36876 +/- 0.7163

Goretex 1.5mm, cosmic muon event



run

Chi2 = 30.2152
NDf = 34
slope = -0.468347 +/- 1.24348

slopes are consistent with 0

citations

https://www.ipmu.jp/ja/research-activities/research-program/XENONnT

New Astronomy Reviews   Volume 49, Issues 2–6, May 2005
The XENON dark matter search experiment

http://www-sk.icrr.u-tokyo.ac.jp/sk/detector/odpmt-e.html

XENONnT : The next step in XENON Dark Matter Search
Uwe Oberlack's presentation at IDM2018

http://www.versandmittelprofis.de/10-lfm-Tyvek-Hardstructure-110g/qm-weiss

https://item.rakuten.co.jp/fujipacking/10000009/