博士論文公聴会の公示（物理学専攻）

学位申請者：　Bui Tuan Khai

論文題目：Energy resolution of CANDLES detector for studying neutrino-less double beta decay of ^{48}Ca
(^{48}Ca　のニュートリノを放出しない二重ベータ崩 壊 を 研 究 す る た め の CANDLES 検出器のエネルギー分解能)

日時：　2020 年 6 月 16 日（火）　16:50 — 18:20

場所：コロナウイルス感染防止のため、オンラインにより行う。URL 等については、学内の方は下記参照。

https://www.phys.sci.osaka-u.ac.jp/naibu/kouchoukai.html

学外の方は主査：能町（nomachi[at]rcnp.osaka-u.ac.jp　[at]=@）に問い合わせること。

主査：　能町正治

副査：　嶋達志、野海博之、吉田斉、青木正治

論文要旨：

Neutrino-less double beta decay ($0\nu\beta\beta$) is a useful tool to determine the mass of neutrino. The CANDLES experiment is searching for the $0\nu\beta\beta$ of ^{48}Ca using CaF_2(pure) scintillator crystals as the detector and the source. Searching for $0\nu\beta\beta$, the two-neutrino double beta decay ($2\nu\beta\beta$) is unavoidable background around Q-value of ^{48}Ca. The difference of the energy spectrum is the only way to discriminate the $0\nu\beta\beta$ events from $2\nu\beta\beta$ events. Therefore, energy resolution must be improved. Scintillation photons are collected by the Photomultiplier Tubes (PMTs) surrounding the crystals. Ideally, the energy resolution should be equal to the statistical fluctuation of number of photoelectrons. The current energy resolution (2.6% r.m.s.) is bigger than the statistical fluctuation of number of photoelectrons (1.6% r.m.s.). The difference is studied in this thesis.

Due to a long decay constant of CaF_2 (τ=1μsec), we make a signal integration of 4μsec to calculate the energy. A Flash Analog-to-Digital Converter records the waveform in each PMT. The baseline fluctuation is accumulated in the signal integration, and they make the energy resolution worse. In this thesis, a study of the baseline fluctuation in CANDLES III detector is reported. The baseline fluctuation can cause a severe effect (about 1% r.m.s.) at Q-value of ^{48}Ca.

In order to reduce the baseline fluctuation, photon counting method is useful. However, because of the signal overlap, photoelectrons can be missed in counting, and the energy resolution becomes worse. To reduce the baseline fluctuation and avoid count loss of the photoelectrons, an alternative method named “partial photon counting” is introduced. Using this method, we obtain the improved energy resolutions 4.5-4.0% (r.m.s.) at 1460 keV (γ-ray of ^{40}K), and 3.3-2.9% (r.m.s.) at 2614 keV (γ-ray of ^{208}Tl). The energy resolution at Q-value is estimated to be improved to 2.2% by using “partial photon counting”. With the improved energy resolution, the sensitivity of CANDLES detector for the half-life of $0\nu\beta\beta$ of ^{48}Ca can be improved by 1.09 times. Additionally, a chance to improve detector resolution by using CaF_2(pure) at low temperature and photon counting is discussed. It is estimated to achieve the new world-best limit of effective neutrino mass of 27-118 meV.