

# 墳 Q(fun-Q) project : muography of Japanese ancient mounds by high school students



**Miki Ohtsuka,<sup>a,b,\*</sup> Kenshiro Aoki,<sup>c</sup> Kana Hashizume,<sup>c</sup> Yuna Ishii,<sup>c</sup> Tomoyo Ishizawa,<sup>c</sup> Sogo Kimura,<sup>c</sup> Sotatsu Ogata,<sup>a</sup> Yuki Okamoto,<sup>a</sup> Satoshi Ono,<sup>c</sup> Asahi Shiozaki,<sup>c</sup> Yuga Takemori,<sup>c</sup> Rino Tomiku,<sup>c</sup> Wakana Yanagimoto,<sup>c</sup> Masaaki Higashide,<sup>d</sup> Tsutomu Ishikawa,<sup>d</sup> Akira Matsumoto,<sup>b</sup> Takeshi Nakamori,<sup>e</sup> Masayoshi Shoji,<sup>f</sup> Shota Takahashi<sup>g</sup> and Kazuki Ueno<sup>h</sup>**

<sup>a</sup> Waseda University Honjo Senior High School

239-3 Kurizaki, Honjo, Saitama, Japan

<sup>b</sup>RIKEN

2-1 Hirosawa, Wako, Saitama, Japan

<sup>c</sup>Waseda University

1-104 Totsukamachi, Shinjuku, Tokyo, Japan

<sup>d</sup>SOKENDAI, Institute of Particle and Nuclear Studies

1-1 Oho, Tsukuba, Ibaraki, Japan

<sup>e</sup>Yamagata University, Department of Physics

1-4-12 Kojirakawa, Yamagata, Japan

<sup>f</sup>KEK

1-1 Oho, Tsukuba, Ibaraki, Japan

<sup>g</sup>Nagoya University, KMI

Furo-cho, Chikusa-ku, Nagoya, Japan

<sup>h</sup>Osaka University, Department of Physics

1-1 Machikaneyama, Toyonaka, Osaka, Japan

E-mail: [m\\_ohtsuka@waseda.jp](mailto:m_ohtsuka@waseda.jp)

墳 Q(fun-Q) project is muography (muon tomography) of Japanese ancient mounds (Kofun:古墳) by high school students with interdisciplinary collaboration. Our collaboration consists of high school students and teachers, scientists, engineers, communicators, curators and archaeologists. We have been working on the survey of ancient mounds in Honjo city, and OSECHI (Outreach & Science Education Cosmic-ray Hunting Instrument) detector is used for the measurement. OSECHI detector is a plastic scintillation muon detector which is developed by scientists and students. We conducted measurement at Akiyama Koshinzuka Kofun.

38th International Cosmic Ray Conference (ICRC2023)  
26 July - 3 August, 2023  
Nagoya, Japa



**ICRC2023**  
38th International Cosmic Ray Conference  
The Astroparticle Physics Conference

\*Speaker

© Copyright owned by the author(s) under the terms of the Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License (CC BY-NC-ND 4.0).

<https://pos.sissa.it/>

## 1. Introduction

In recent years, significant academic research has been conducted in interdisciplinary fields, and the importance of such research is expected to grow in the future. For example, the elucidation of the internal structure of the pyramids using muography technique has had an impact on both physics and archaeology [1]. The muography is also of great social significance in applications such as internal fluoroscopy of nuclear power plants and measurement of tsunami[2], and is expected to continue to expand and develop in the future. The interdisciplinary nature of muography of archaeological sites requires the ability to see from multiple perspectives, so this is an appropriate subject for inquiry based learning.

## 2. Collaboration

In fun-Q project, high school students are supported by interdisciplinary collaboration. Teacher coordinates students' activity, scientist and engineer engages on the development of equipment and instruction for students. Graduate students helps students work such as coding, processing the data. Therefore from an archaeological perspective, Honjo Waseda No Mori museum and Honjo City cooperates in suveying the materials and tombs.

## 3. Activity

The students' activities are study sessions, group work, measurement at Kofun, and presentation in conferences.

### 3.1 Group work

About 10 students are divided into three groups: the Kofun Group, the Hardware Group, and the Software Group.

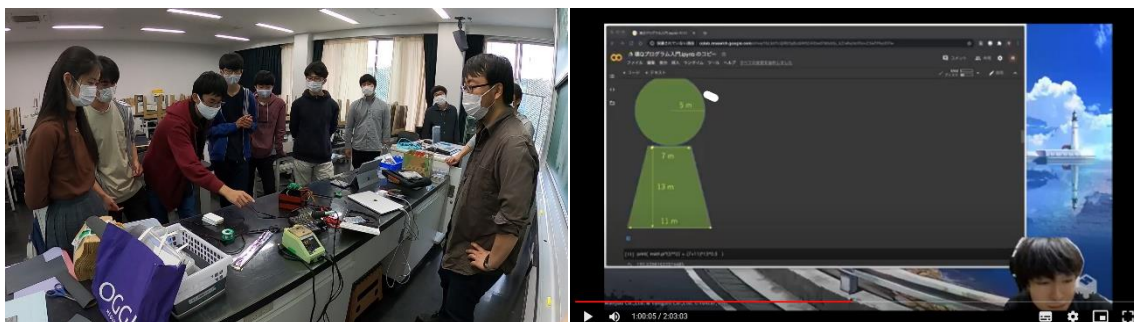
Kofun Group:	With the cooperation of the museum, students conduct literature research, visit ancient tombs in Honjo city for finding the good target (Figure 1).
Hardware Group:	Students develop and assemble the OSECHI detector and examine the design of measurement with scientists and engineers.
Software Group:	Students analysis using Python code and investigate the characteristic of OSECHI detector with draduated students.



**Figure 1:** Tour of the ancient mounds in Honjo city by Kofun Group. This mound is Kanasana Jinja Kofun. Because the shrine is built on top of a burial mound, destructive survey is difficult.

### 3.2 Seminar and workshop

In fun-Q project we had various seminar and workshop. Each topic of seminar is by speaker from various fields, not only particle physics, but also ancient tombs, soldering technology, GNSS, providing interdisciplinary knowledge. And students also had talk about geophysical exploration. Workshops are ongoing along with student activities. For better understanding the detection method and DAQ system, assembling the OSECHI detector and using Arduino workshop is held in person. As the next step, coding and analysis workshops are carried out about 10 times. Graduate students have online lectures to high school students using google colaboratory. The lectures cover the basics of Python, how to read data, and specific analysis method.



**Figure 2:** At the OSECHI detector workshop, students deepen their understanding by hands-on operation following the scientist's instructions in the classroom(left). In online workshops, graduate students show the examples, guiding students to perform the analysis on their own.(right).

### 3.3 Measurement

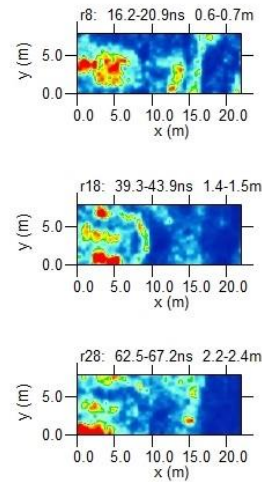
The first measument was performed at Akiyama Koshinzuka Kofun(秋山庚申塚古墳), which is located near the school and whose internal structure is already known. We conducted Ground Penetrating Radar (GPR) survey and measurement of cosmic muon using the OSECHI detector. This measurement is for knowing the characteristics of the OSECHI detector in outdoor environment, and getting more information by comparing the data of the GPR survey, which has already been used to investigate the internal structure of the Kofun[3], and that of the OSECHI detector.



**Figure 3:** Akiyama Koshinzuka Kofun (photo by Yuichi Inoue)

#### 3.3.1 GPR survey

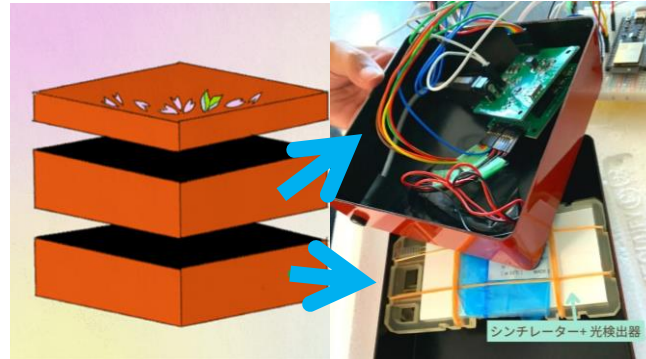
In GPR survey, the radar reflection intensity is measured to determine the shape of subsurface structures. We examined GPR survey at Akiyama Koshinzuka Kofun, supported by Honjo city and graduated students of archaeology courses in Waseda University.



**Figure 4:** GPR survey on the top of Akiyama Koshinzuka Kofun by high school students and graduated students of archaeology course(left). Dependence of radar reflection intensity on distance from the ground surface  $z$  (right).  $z = 0.6 - 0.7$  m (top),  $z = 1.4 - 1.5$  m (middle),  $z = 2.2 - 2.4$  m (bottom).

### 3.3.2 OSECHI measurement

When cosmic muons pass through the OSECHI detector, the signal from stacked 3 plastic scintillator plates is sent to electronics via photodetectors. Then for measurement at Akiyama Koshinzuka Kofun, we used portable power supply with a solar cell.\*



**Figure 5:** Illustration(left, by high school students) and photo(right) of OSECHI



**Figure 6:** Measurement of cosmic muon using OSECHI

### 3.4 Presentation at Conference

Students have participated in the poster presentation by high school students at the Japan Geoscience Union 2021 Congress (JpGU) and the high school students' poster session at the 88th General Meeting of the Japanese Archaeological Association. For the presentation, students had the opportunity to consider the results of their activities from both scientific and archaeological perspectives.

\*For more details, see [PO\_E1-12] Development of Japanese-style cosmic-ray muon detector for outreach and education.



**Figure 7:** Online poster presentation of JpGU(left), and Poster Session of the 88th Annual Meeting of the Japanese Archaeological Association at Waseda University(right)

#### 4. Perspective

Future prospects are to examine the results of the measurements at the Akiyama Koshinzuka Kofun, to understand the characteristics of the OSECHI detector, and to improve it. Furthermore, next measurements will be made in ancient tombs whose internal structure is not yet known. And we plan to perform educational evaluation of the fun-Q project.

#### Acknowledgment

Fun-Q project is supported by SOKENDAI and The Shimonaka Memorial Foundation.

Special thanks for  
 Honjo City: Division for the Protection of Cultural Properties,  
 Honjo Waseda no mori Museum: H. Ota, Y. Matsuhashi,  
 Waseda University: M. Baba, Y. Inoue,  
 Graduated students of archaeology course,  
 Waseda University Honjo Senior High School:  
 K. Takahashi, Y. Kawamura,  
 and M. Sasaki.

#### References

- [1] K. Morishima et al, *Discovery of a big void in Khufu's Pyramid by observation of cosmic-ray muons*, *Nature* 552, 386-390, 2017
- [2] HKM. Tanaka et al, *Atmospheric muography for imaging and monitoring tropic cyclones*, *Scientific Reports* 12, 16710, 2022
- [3] For example: Masahiro BABA, Masayoshi JOKURA et al, *Report of a three-dimensional survey and GPR research on the Sakitama-Futagoyama Tumulus in Saitama Prefecture, Japan WASEDA RILAS JOURNAL* 7, 377-388, 2019