

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



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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. The students are divided into groups, working with experts in both archaeological and physics research and combining the results of their studies. First target is Akiyama Koshinzuka Kofun (秋山庚申塚古墳) located near our school. We conducted Ground Penetrating Radar (GPR) survey and cosmic ray measurement using a unique Japanese-style cosmic-ray muon detector for outreach and education, the OSECHI detector there.

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1. Introduction

In recent years, significant academic research is being conducted in interdisciplinary fields that integrate the humanities and sciences, and the importance of such research is expected to grow in the future. In particular, the elucidation of the internal structure of the pyramids using cosmic ray muography has had an impact on both physics and archaeology [1]. Furthermore, muography technique is used for a lot of socially meaningful applications such as a survey of nuclear power plants and a measurement of tsunamis [2]. Because of its interdisciplinary nature, studying the muography of archaeological sites requires the ability to see things from multiple perspectives, so it is a suitable subject for inquiry activity. The purpose of this study is to develop an educational program, teaching materials, and collaboration to conduct interdisciplinary research on muography of ancient tombs that combines particle physics and archaeology by high school students.

2. Collaboration

In fun-Q project, high school students are supported by interdisciplinary collaboration. Teachers coordinate students' activities. Scientists and engineers engage in the development of equipment and instruction for the students. Graduate students help high school students with coding and processing the data. In addition, from an archaeological perspective, Honjo Waseda No Mori Museum and Honjo City cooperate in surveying the tombs for students. And then, when measuring, all collaborators join their efforts together.

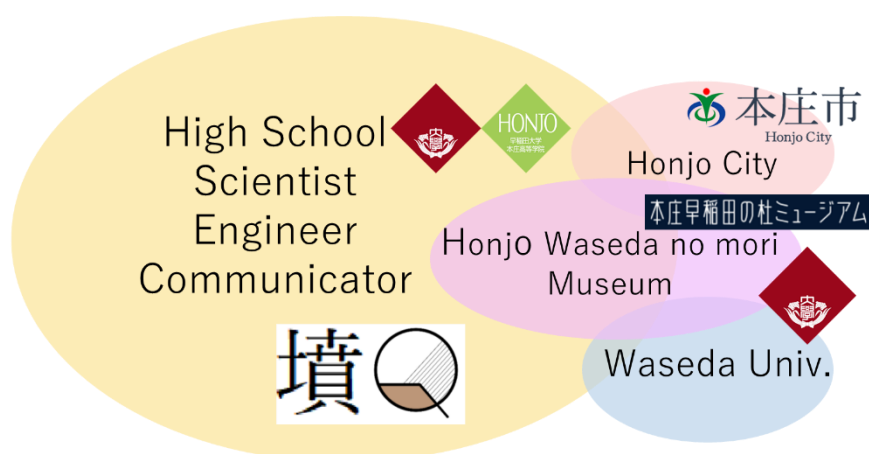


Figure 1: Fun-Q collaboration

3. Activity

The students' activities are seminar and workshop, group work, measurement at Kofun, and presentation at conference.

3.1 Seminar and workshop

In fun-Q project, we have various seminars and workshops. Each topic of the seminars is from various fields, not only particle physics but also ancient tombs, soldering technology, GNSS, etc, providing interdisciplinary knowledge. And sometimes students also give talks. Workshops are ongoing along with student activities. For a better understanding of the detection method and the DAQ system, assembling the detector workshop is held in person. As the next step, coding and analysis workshops using Python 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 the data and specific analysis methods.

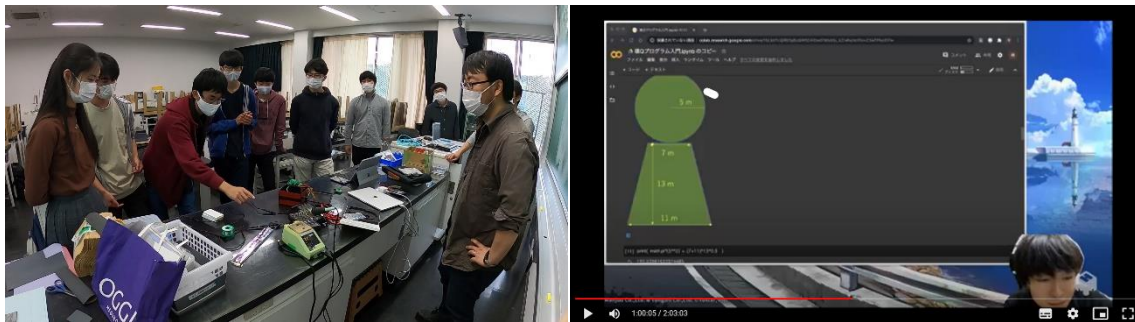


Figure 2: At the detector workshop, students deepen their understanding by hands-on operation following the scientist's instructions in the classroom(left). In online workshops, graduate students show examples, guiding students to perform the analysis on their own. (right).

3.2 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 and visit ancient tombs in Honjo city for finding good targets.
- Hardware Group: Students develop and assemble the detector and examine the design of measurement with scientists and engineers.
- Software Group: Students analyze using Python code and investigate the characteristic of the detector with graduated students.



Figure 3: Tour of the ancient mounds in Honjo city by Kofun Group. This mound is Kanasana Jinja Kofun. Because the shrine is built on the top of the burial mound, destructive surveys are difficult.

3.3 Measurement

The first measurement 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 cosmic muon measurement using the OSECHI detector [3].



Figure 4: Akiyama Koshinzuka Kofun (photo by Yuichi Inoue)

3.3.1 GPR survey

GPR survey has already been used to investigate the internal structure of the Kofun [4]. In GPR survey, the radar reflection intensity is measured to determine the shape of the subsurface structure. We examined GPR survey at Akiyama Koshinzuka Kofun, supported by Honjo City and the archaeology course of Waseda University.

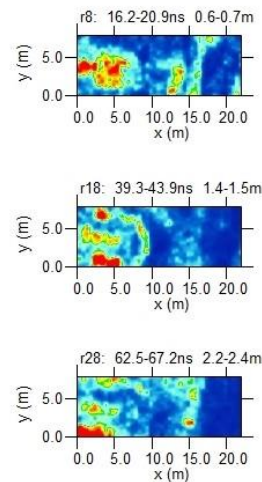


Figure 5: GPR survey on the top of Akiyama Koshinzuka Kofun by high school students and graduated students of archaeology course(left). Dependence of the radar reflection intensity on the distance from the ground surface z (right). $z = 0.6 - 0.7$ m (top), $z = 1.4 - 1.5$ m (middle), $z = 2.2-2.4$ m (bottom).

3.3.2 OSECHI measurement

The OSECHI (Outreach & Science Education Cosmic ray Hunting Instrument) detector is Japanese-style cosmic-ray muon detector for outreach and education. 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, a portable power supply with a solar cell is connected to the OSECHI detector. This measurement is for knowing the characteristics of the OSECHI detector in the outdoor environment and getting more information by comparing the data of GPR and that of the OSECHI detector.

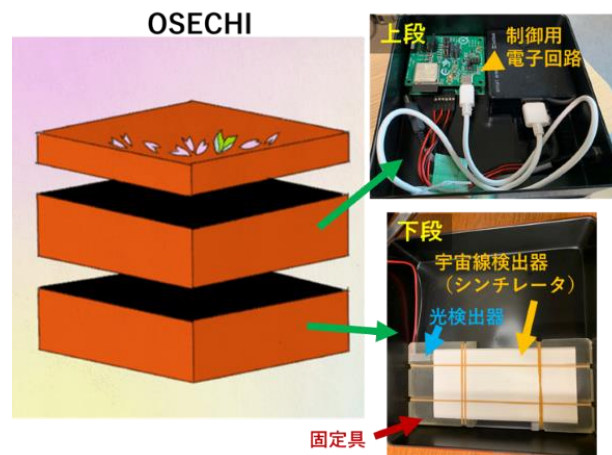


Figure 6: Illustration and photo of the OSECHI detector



Figure 7: Measurement of cosmic muon using the OSECHI detector

3.4 Presentation at Conference

Students have participated in the poster presentation for 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.



Figure 8: 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

The data of the measurements at the Akiyama Koshinzuka Kofun is under analysis. Next measurements will be made in ancient tombs whose internal structure is not yet known. In addition, we are beginning an educational evaluation of fun-Q project. Students' feedback indicates that students realize the importance of both expertise and removing barriers between fields, it can be seen that fun-Q project promotes students' understanding of interdisciplinarity and respect for different fields.

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