PROCEEDINGS OF SCIENCE

Online support for research activities by high school and junior high school students

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Accel Kitchen LLC has launched Japan largest cosmic-ray outreach network providing handy cosmic-ray detectors to more than 100 high school and junior high school students and supporting their research activities remotely with online communication tools. There are over 30 various and unique research topics conducted by students e.g. measurement of the cosmic-ray flux at Japan's highest mountain Mt. Fuji to investigate the relationship with altitude, comparison of cosmic-ray flux with sunspot counts observed by the school's telescope, collaboration with students in Argentina to compare the cosmic-ray flux between Japan and Argentina to observe the effect of the South Atlantic Anomaly. Online research support by undergraduate and graduate students enables them to conduct scientific research and some of their progress has been published in peer-review papers.In this presentation, we will introduce their research activities.

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1. Background

Accel Kitchen LLC [1] provides various handy particle detectors for high school and junior high school students mainly in Japan. We also build a research network of students, mentors, and researchers using text/voice chat. There are various educational activities in cosmic rays around the world, but the development of an inexpensive, quantitative detector in the tens of thousands of yen range and its use in ongoing exploratory activities is unprecedented in the world. We have more than 30 teams of 100 participants, each supported by more than 10 researchers and 14 undergraduate and graduate students. We are expanding the number of cases of collaborative research not only within Japan, but also with other countries [2]. We present our current community shown in figure 1.

Figure 1: Schools participating in our community in July 2023.

In this section, we'd like to introduce our support scheme. We create an environment for middle and high school students with a vague interest in particle physics and space to spend not just a day but a year immersed in it. This is because not many middle and high school students who are interested in space know about cosmic rays, and it is rare for them to get to access detectors and experimental facilities themselves. Our first priority is to conduct support activities over a long-term period. By conducting activities over a long-term period, we also aim to raise the resolution of the desire to do research in the future.

First, we recruit middle and high school students interested in our activities from a 1-day cosmic ray outreach event. The purpose of this event is to understand how cosmic rays work by assembling a simple cosmic ray detector and know the invisible cosmic ray. We then select students from among the event participants who are particularly interested and give them research topics. These activities can be done by individuals alone, not in the form of clubs that take place in schools. In fact, we have an online community, where researchers/university students and middle and high school students discuss through Discord [3].

Most students use cosmic watch(CW), an easy-to-handle cosmic ray detector [4] for the hardware part, but some students build their own simple detectors. Students also analyze the data with Python at Google colaboratory [5]. How to handle these detectors and how to write analysis codes are all discussed through Discord, and all our activities are done online.

Our activities sometimes require a lot more study and work than is required in school, and students need a lot of help. Undergraduates, primarily in physics, help students with their analyses and experiments.For college students, this activity also gives the outreach experience they need for their academic careers. This educational system is an "ecosystem" of college students, and the college students who were middle and high school students are the primary mentors of the students. One testament to the success of this program is that some students have gone on to college and returned as mentors through this activity.

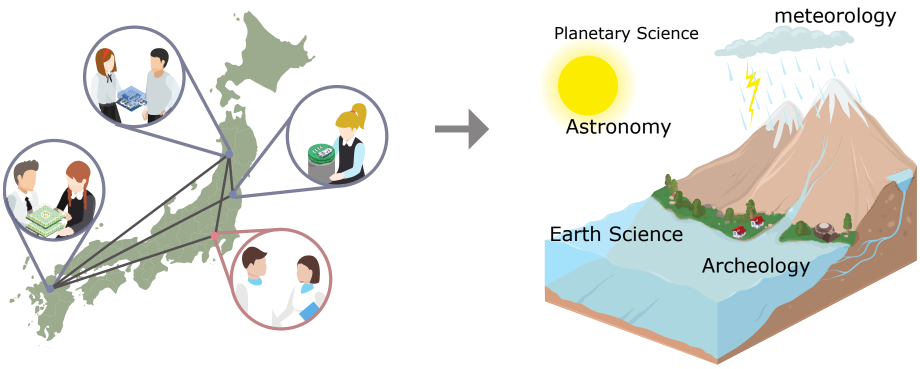

Figure 2: Our support scheme for students and various research related to cosmic rays.

2. Example of research by students

In this section we present examples of research activities conducted by some Japanese junior and senior high school students. Through continuous support, students has achieved many scientific results, including the publication of a peer-reviewed academic paper [6] authored by a junior high school and high school student.

2.1 Fault structure explored by radon detector

Students at Yokote High School are investigating rocks near the river. The left panel of Figure 3 shows the simple radon detector [7] , this detector can measure α-decay from daughter nucleus of radon. Details of the radon detector and other detectors developed by the students will be presented in K.S. Tanaka et al. (2023) [9] . Using the detectors, they measured uranium-series isotopes in rocks, soil, and rivers. The right panel in Figure 3 shows a graph of detected α-decay from rocks. They successfully detected α-rays from the nuclide with energies corresponding to α-decay.

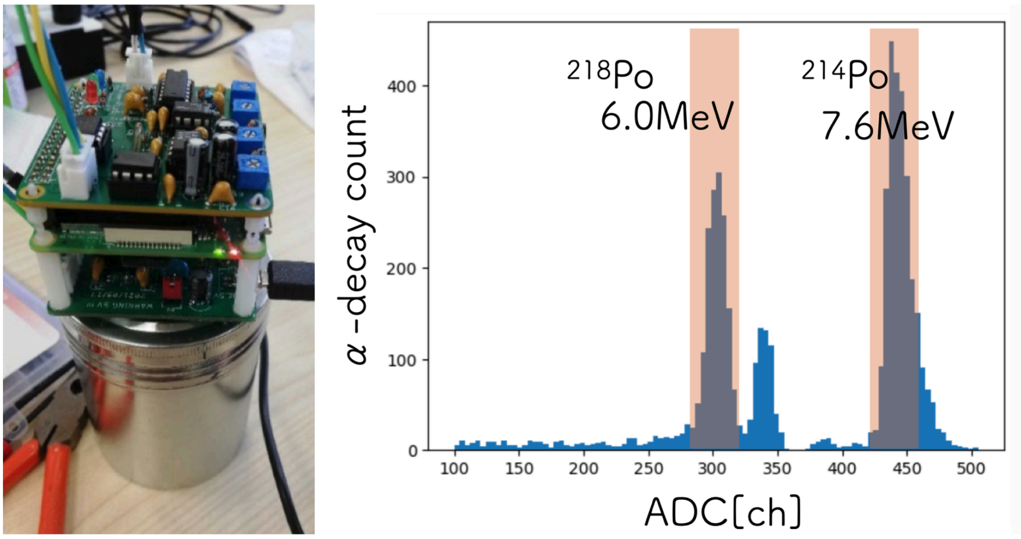

Figure 3: (Left) Radon detector developed by students. (Right) Measurement of α-decay from daughter nucleus of radon in the rock.

2.2 Visualisation of dose distribution using scattered radiation

Proton beam therapy is a type of radiation therapy with high dose concentration. Therefore, it requires high precision delivery, but a method to measure dose distribution in real time has not been established. When proton beams are delivered to the body, scattered radiation is generated from the irradiated area. In this study, it assume that the dose distribution in the body could be estimated by detecting these scattered proton beams, and experiments were conducted both in simulation and in an accelerator. Based on these results, we investigated whether the dose distributions could be estimated in the same way using a scintillation detector, which is inexpensive and compact. The study was conducted using the PHITS Monte Carlo code provided by the Japan Atomic Energy Agency, which simulates various radiation behaviors in any material. Based on these results, we submitted a proposal to the Beamline for School competition [8] an international physics competition for high school students organized by CERN, and were selected as a shortlist.

3. Conclusion

Supported by numerous mentors and researchers, our cosmic ray research activity is broadly functioning in Japan. This project involves conducting advanced research activities that sometimes transcend standard curricula, a fact that has been proven to be highly educational for both middle and high school students as well as university student mentors.

From the students' perspective, this activity not only promotes their research but also allows them to observe other middle and high school students engaged in similar research activities. Furthermore, through biannual regular workshops, they can connect with experts, sometimes even

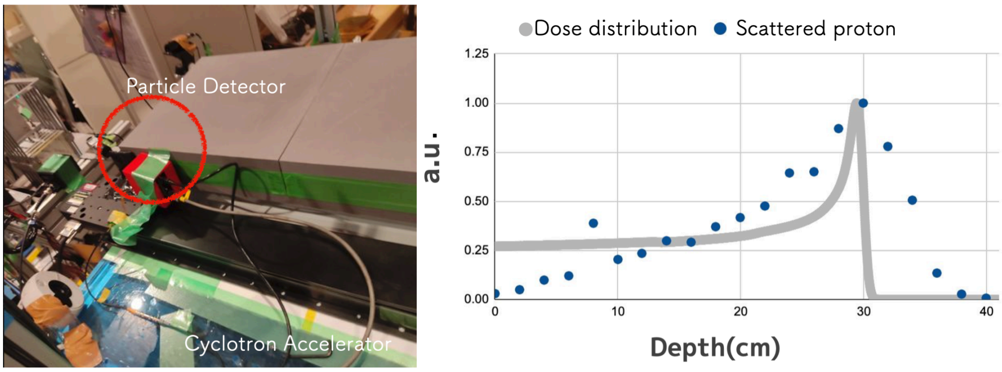

Figure 4: (Left) Proton irradiation using the AVF cyclotron accelerator at CYRIC, Tohoku University. The detector was moved along the phantom to obtain the dose distribution due to scattered protons. (Right) Measured values are shown as blue dots, and the solid gray line shows the dose distribution calculated by a Monte Carlo simulation code called PHITS.

those outside our team. Such research activities become possible not through one-day to one-week events, but rather through consistent support. Going forward, our goal is to expand these support activities to more students and broaden the scope of research. We will also collect objective indicators and data in order to evaluate the results of our educational projects. [10, 11]

4. Acknowledgment

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