Symphonies in the Colliders: Investigating the Musical Signatures of Particle Beams

Chinmay Pala, Izma Khan, Kalash Bhaiya, Monica Sing, Nikhil Kulkarni, Riddhiman Bhattacharya, Sanvi Gupta

April 2023

1 Why CERN

The Pied Pipers are a group of high-school students from across India and Cambodia with varied interests and experiences but a common love for physics! Visiting CERN has been THE dream for each one of us. While working on this project, we were able to catch a glimpse of the incredulous depth of particle physics. The idea of getting a chance to not just witness, but actually contribute to advancement of the sciences is mind-blowing! We are incredibly excited to explore the massive accelerators at CERN, learn about different projects and implement our experiment on a grander scale. As Albert Einstein's famous quote goes:

> *'After a certain high level of technical skill is achieved, science and art tend to coalesce in esthetics, plasticity, and form.'*

In the vast universe that surrounds us, art and science are intertwined threads which weave a tapestry of beauty and wonder. Our goal is to unite particle physics with music - to give voice to the harmonies of subatomic particles. Hence we propose a study of the variation and characteristic musical interpretation of particle beams; while also addressing a pragmatic aspect: studying the composition of the CERN-T9 beamline.

2 Theoretical Background

The central idea of our experiment is extracting characteristic music notes from accelerated particle beams at the T9 beamline. We plan to use Bending Magnets for separating the trajectories of the different particles in the beamline, and record their impact using MicroMegas detectors to obtain their exact positions. Once we get the exact coordinates (x, y) in millimetres of each particle, the next step is to associate each of these coordinates with a frequency. We use the y-coordinate to assign a frequency to the particle, and the x-coordinate to determine the duration of the note. The frequency can be calculated on various scales. Whichever scale suits the experimental data can be adopted. An example could be the exponential scale:

$$f = 2^{\frac{y}{t}} \tag{1}$$

Where y represents the y-coordinate of the point obtained from the MicroMegas detector, and t is a constant whose value would be proposed empirically to keep the frequencies in range. The duration for which the note will be played can be worked out as:

$$duration = \frac{x}{10} \times std \tag{2}$$

Where x represents the x-coordinate of the point obtained from the MicroMegas detector, and std is a fixed duration of time for which a general note is played.

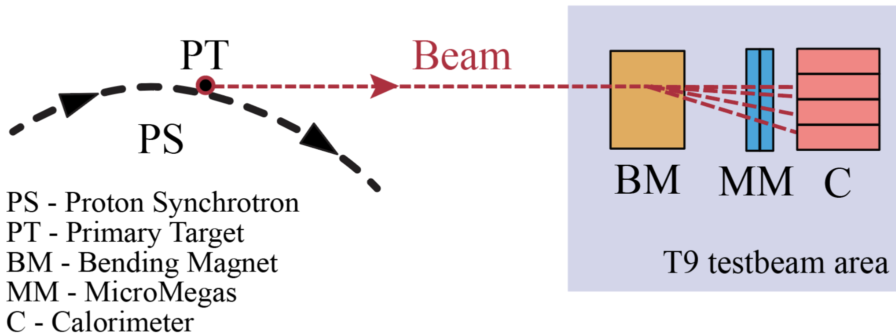

Figure 1: Experimental setup diagram illustrating

The volume or loudness of the note will be determined based on the energy of the particle, using the below formula:

$$volume = k \times E \tag{3}$$

Where k is a constant that determines the scaling of the loudness with energy, and E is the total energy of the particle, as measured by the calorimeters. The value of k can be proposed empirically based on the desired volume of the musical note. Hence, the frequency f obtained will be converted into a MIDI note and played for the respective duration with the respective loudness.

3 Experiment Setup and Observations

The set-up is as follows (Figure 1):

1. Standard set up consisting of the Proton Synchrotron (PS) and Primary Target (PT), where the beam generated can be positively or negatively charged.

2. In the test beam area, a Bending Magnet (BM) is placed in the beam's path. Each type of particles contained in the beam are diverged to varying degrees according to their charge and mass. The magnetic field value will be set to a constant.

3. Two MicroMegas detectors (MM) of dimension 40x40cm are stacked such that their axes are perpendicularly aligned. This tracks the position of the diverged particles incident on the 2D plane perpendicular to the original beam.

4. 16 Lead Crystal Calorimeters (C) are arranged in a 4x4 square. This covers an area of 40x40cm, thus sufficiently capturing the energy of all particles passing through MM.

Our experiment aims to compare the musical notes for different types of beams, for varying magnetic field, and for different ways of calculating the frequency or the loudness of the note. Table 1 can be updated with the results of the experiment, which will then be analysed to find correlations and causations.

Magnetic Field Intensity	Beam Dispersion	Frequency of Major Note
...	...	...
...	...	...
...	...	...
...	...	...
...	...	...

Table 1: Observation Table

4 Conclusion and Takeaways

With this proposal, we wish to conclude the answers to questions like:

- Is there geometric symmetry in our findings? If not, what do atypical patterns indicate?
- Are all characteristic notes of a particle beam, say a proton beam, the same?
- What differentiates the music produced by these beams? Can we use it as a basis for identifying beam composition?

Since the empirical access is limited, we can predict that on an average, given an ensemble of particles, there might be an overall coherence and pattern — even if the beam has largely same particles, the noise can create this harmony and break from monotony of similarity. We hope to deepen our understanding of subatomic trajectories and even discover creative methods to effectively calculate the purity of the T9 beamline. Art + Physics is an emerging field, and this experiment could be an amazing model for outreach - our team plans to create a short documentary, showcasing the beauty of particle physics through audio-visual means.

5 Acknowledgements

We are grateful to CERN, for this opportunity to work on particle physics experiments and get an idea of how research feels like at the highest level! We are also immensely thankful to our mentor, Mr. Shyam Wuppuluri for his constant support and motivation throughout our journey.

6 References

1. Lee, Rhodi. 2015. "CERN Scientists Make Music Using Particle Physics And 'Cosmic Piano.'" Tech Times.

2. McKinnon, Mika. 2019. "Upcycled instrument tied to auspicious accelerator " Symmetry Magazine.

3. The University of Manchester. 2020. "Sound of the Underground: making music from particle physics - Department of Physics and Astronomy Blog." Science and Engineering blogs.

4. Evans, Margaret. 2016. "Music of the (data) spheres. Massachusetts Institute of Technology." MIT News.

5. Alexis Kirke, Eduardo Miranda, Antonino Chiaramonte, Anna R. Troisi, John Matthias, Nicholas Fry, Catherine McCabe, Jeff Radtke, Martyn Bull. 2013. "Cloud Chamber: A Performance with Real Time Two-Way Interaction between Subatomic Particles and Violinist". MIT Press.

7 Outreach Activity

Effective science communication, inclusive classrooms, learning environments and outreach activities are vital for the development of science and technology, and upliftment of the society. Our team members have access to several platforms and necessary resources to undertake scientific exposure initiatives which can have an impact on the lives of disadvantaged kids.

After performing the experiment at CERN, we plan to create an audio-visual demonstration of Art + Physics (an extended version of our BL4S video) to be shared with schools and local educational clubs and societies. We will continue scientific enrichment activities through non-profit organizations such as FLY (Fun Learning Youth) and RAM (Raising a Mathematician Foundation) which strive to bridge the educational gap and spark scientific interest in school students. The focus is free sessions, activities, and the use of hands-on learning as a tool for effective understanding of subjects. Recently, an astronomy seminar and hands-on telescope-making session was held in Nashik, India -

Participating in BL4S is an experience which we will cherish for our lifetime. Irrespective of the outcome of the competition, the Pied Pipers pledge to actively contribute towards scientific outreach, envisioning a world where scientific ideas, education and resources are freely accessible to everyone.