Measuring The Particle Composition of the T9 Beamline

Team Particular Perspective
Pakistan

I. Introduction

This paper presents a proposal for the CERN BL4S competition, which relates to the application of a particle accelerator at CERN, specifically using the T9 beamline. In scientific literature, the importance of the composition of the particle beam has been emphasized in a myriad of applications that require information and control over the particle beam composition. These applications include radiotherapy, beam behavior, and high-energy physics experiments, such as neutrino oscillation experiments where knowing the composition of the beam is critical. This is because different neutrinos have different probabilities of oscillating between flavors as they travel through matter. Additionally, precision electroweak experiments require high accuracy and minimal variation in the number and energy of the particles, and hadron therapy is affected by the composition of the beam, as it determines the radiation dose injected in the tumor as well as the surrounding healthy. Under this light, we outline an experiment that uses the T9 beamline to effectively measure the particle beam composition using relevant experimental equipment and theoretical analysis to support our experiment.

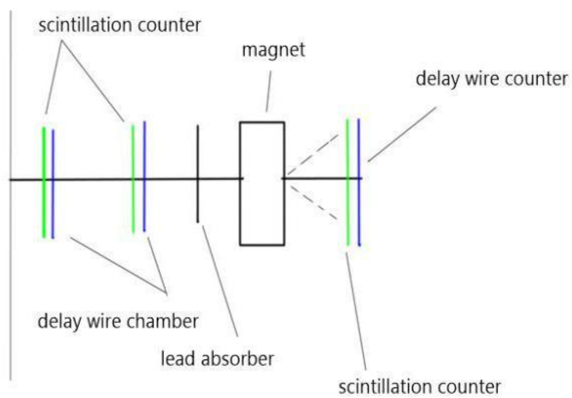
A. Why we want to go

We are all current senior high school students studying in Pakistan, chained with high passion and curiosity for Physics. With the desire to acquire knowledge and finding answers to the unanswered, we strive to imprint a positive footprint on society by fulfilling gaps that exist and improving preexisting systems by utilizing our knowledge and integrating them across multiple disciplines and, in particular, physics. The opportunity of visiting and working with a synchrotron would be largely invaluable in terms of gaining experience and understanding the practicality that is inhabited in performing experiments. Furthermore, winning the first prize will aid in further diffusion and promotion of science around Pakistan and educational institutions. For these reasons, such opportunities can help us make progressive transitions in the near future in terms of our understanding of scientific reasoning and also helping society.

B. Experimental Setup and Methodology

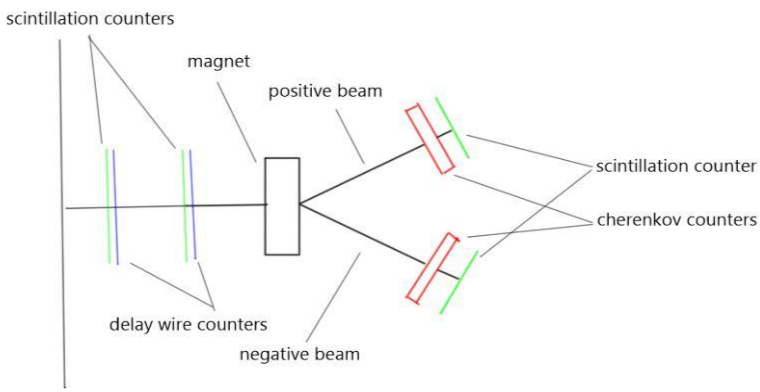
We will be using a variety of absorbers and detectors to filter out and detect the various particles that will be present in varying amounts in the T9 beamline at CERN. One piece of information about the beamline we will be relying on is that the beamline is selected by impinging a beam from the proton synchrotron on a target, and then separating the resulting secondary beam with a magnetic field, selecting the particles at appropriate momentum using a collimator. Thus all the particles in the beam, we will be receiving at the experimental area, will be at the same momentum.

Setup 1



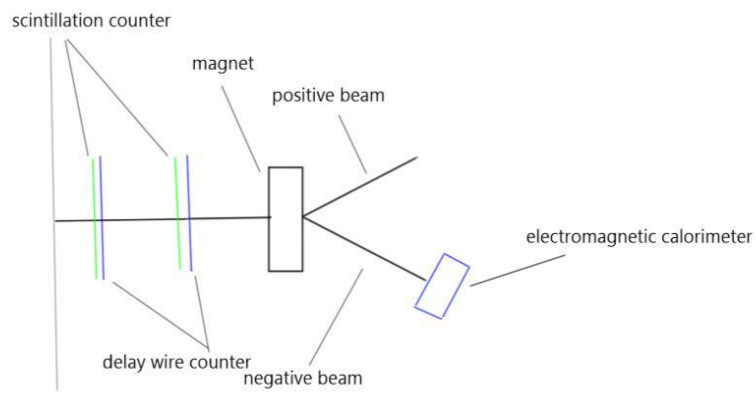
In the first setup we will have a couple of scintillation counters and delay wire chambers to count the total number of particles and to work out the direction of the beam. Next there would be a lead filter to scatter and slowdown the electrons in the beam. After that, we would have a magnetic spectrometer, consisting of a magnet followed by a scintillation counter and a delay wire chamber. The particles that have the same momentum could be counted by calculating the position on the DWC they will be landing on and counting only those.

Setup2



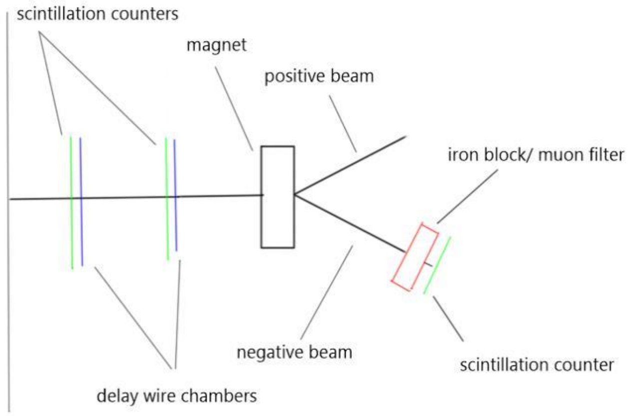
As a second setup, we would remove the lead filter and after the magnetic field, we can select only the beam of positive particles that emerge. Then we would replace the delay wire chamber with a Cherenkov counter followed by a scintillator in the path of the positive beam. We would put a velocity threshold on the Cherenkov counter to only count the particles below a certain mass, since this beam is expected to contain only protons, positive pions, and positive kaons, we could count only the number of pions as they are the lightest amongst these particles. We could, then put the threshold such that both pions and kaons are counted (protons are heavier than both pions and kaons), and then subtract the count from the count in scintillation counter, to get the number of protons. As for the second beam that emerges from the magnet with the negative particles, we could then attach the scintillation counter and Cherenkov counter in front of it, then put a threshold such that only the lightest particles, the electrons, are counted obtain a count of the electrons in the beam.

Setup3



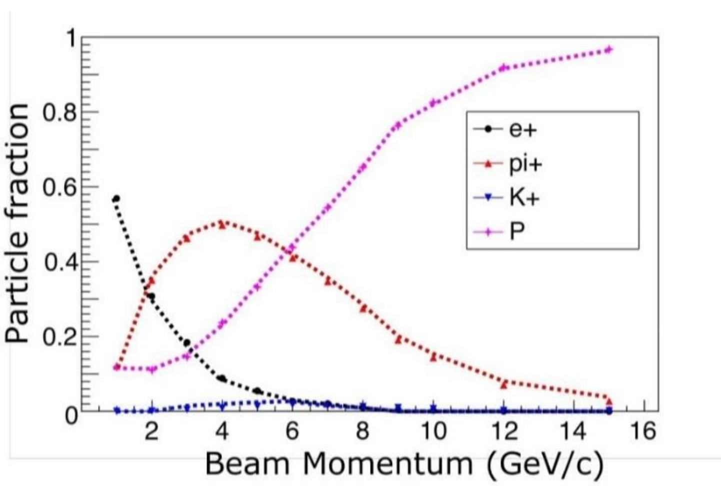
As the third setup, after the magnetic field, on the side of the negative beam we would add an electromagnetic calorimeter instead of the Cherenkov or scintillation counters which would give us the energy of the electrons only. We would then be able to use the momentum of the electrons and their total energy to find a redundant count of the electrons.

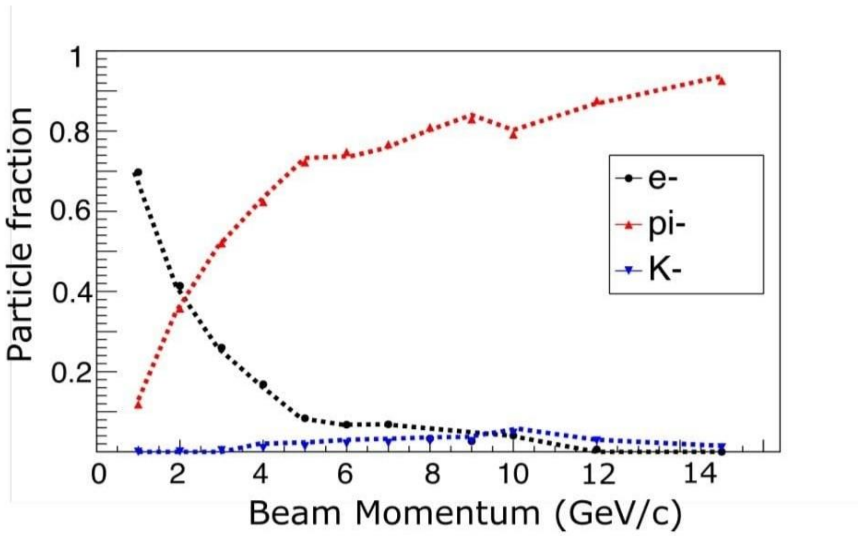
Setup4

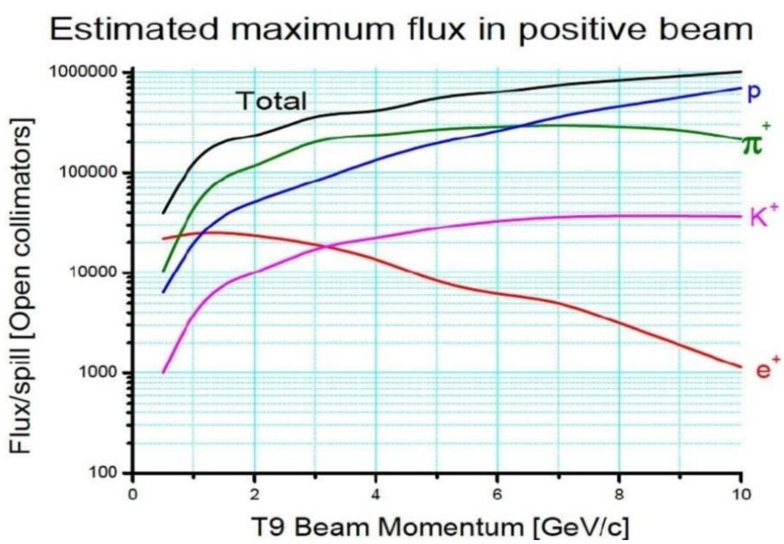


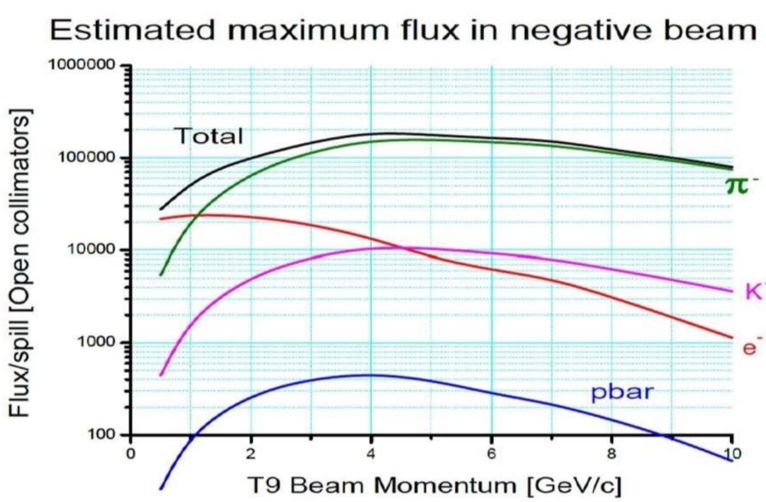
Finally, we could add a massive iron block to act as a muon filter on the previous setup, replacing the electromagnetic calorimeter, and set a scintillation counter after this, thereby obtaining a count of the muons in the beam.

Moreover, the hypothesized results are projected below. The proton beam consists of particles like protons, pions, kaons, positron and electrons. These relationships include the particle fraction and particle flux in relation to beam momentum in the positive and negative beams. These graphs are referenced from official material provided by BL4S.




Particle fraction
Beam Momentum (GeV/c)
e-
pi-
K-
0
2
4
6
8
10
12
14
0.2
0.4
0.6
0.8
1


Estimated maximum flux in positive beam
Total
p
π^+
K^+
e^+
Flux/spill [Open collimators]
T9 Beam Momentum [GeV/c]
1000000
100000
10000
1000
100
0
2
4
6
8
10


Estimated maximum flux in negative beam
Total
π^-
K^-
e^-
pbar
Flux/spill [Open collimators]
T9 Beam Momentum [GeV/c]
1000000
100000
10000
1000
100
0
2
4
6
8
10

C. What we hope to take away

Physics is a discipline that has been undergoing constant evolution. If we are greeted with this opportunity, our scientific thinking, knowledge, experience, skills, and most importantly understanding of the subject would expand significantly. Furthermore, this experience would allow us to further grant us the possibility of giving younger learners in Pakistan opportunity around the scientific society, with emphasis on scientific understanding, research, and how to use science in neutralizing gaps that exist in the world. Beginning with this fruition would only further advocate for this cause. We must develop and think forward for the sustainable future we desire, and this would be our first big step in contribution.

References

Periodicals

[1] Experiment_examples_2023.pdf (beamlineforschools.cern)
[2] information_about_the_t9_beam_line_and_experimental_facilities.pdf (home.cern)
[3] Beams_Detectors_BL4S2022.pdf (beamlineforschools.cern)
[4] Measurement of beam particle composition by J. L. V. Lewellen, D. R. Schuermann, and J. R. Delayen.
[5] Importance of Particle Beam Quality for Medical Applications by Thomas Bortfeld
[6] The ATLAS Experiment at the CERN Large Hadron Collider" by ATLAS Collaboration (2008)
[7] Searching for New Particles at High-Energy Colliders" by Jonathan L. Feng (2017)
[8] Methods for Measuring the Particle Composition of High-Energy Particle Beams by M. Koratzinos et al.