ChDR-CHEESE

Cherenkov Diffraction Radiation - Characteristic Energy Emissions on Surfaces Experiment

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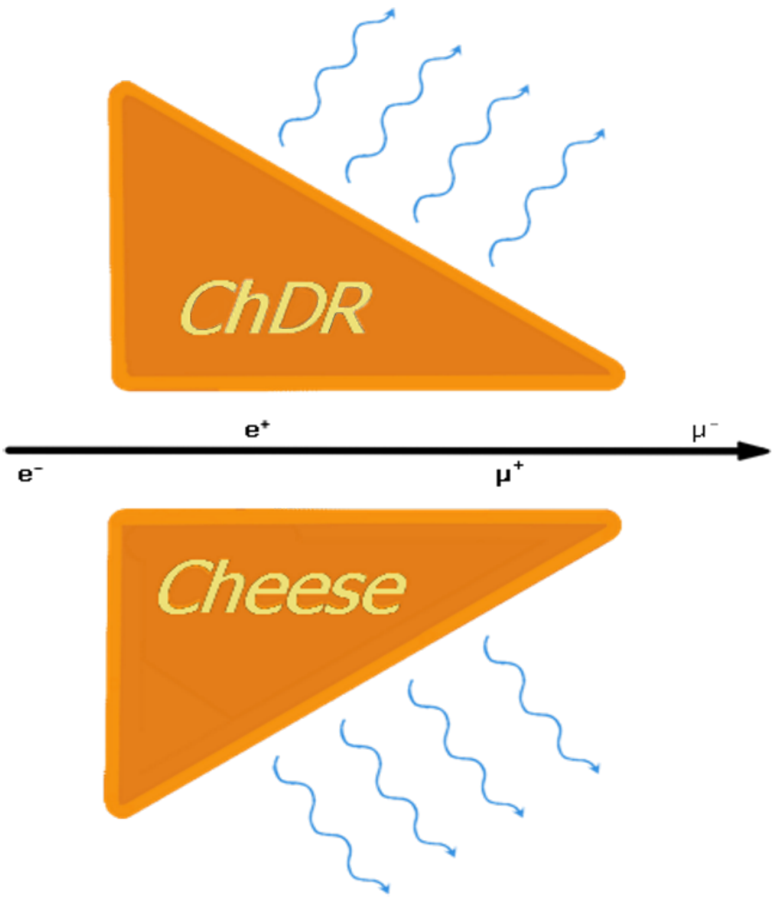

1 Introduction

Beam diagnostics are crucial for smooth accelerator operations. Approaches in the past have mainly focused on technologies where the beam properties are significantly affected by the measurement. Recently, groups have performed experiments for non-invasive beam diagnostics using Cherenkov Diffraction Radiation (ChDR) [1]. Unlike regular Cherenkov Radiation, the charged particles (e.g. electrons and positrons) do not have to move inside of the medium, but it is sufficient for them to move in its vicinity as long as they are faster than the speed of light in the medium. Changes to the beam properties due to ChDR-measurements are negligible and therefore ChDR could be used for non-invasive beam diagnostics in future colliders [2].

2 Why we want to go

We are a group of high school students from Berlin with a great interest in physics. We discovered our passion for particle physics after visiting both the BESSY II synchrotron in Berlin and the LHC at CERN as a part of our physics studies. Since then we continued pursuing an active interest in particle physics, and when we heard about the BL4S competition we decided that we wanted to take part in this once in a lifetime opportunity. We hope to gain first-hand insights into particle physics and to be able to share these insights with our friends and fellow pupils to promote interest and contribute to understanding of physics at our school.

3 Experiment

3.1 Research question

In our experiment we want to focus on the ChDR emitted by electrons and positrons, monitor the beam properties and compare the results. Can we identify differences between both of those beams? We would further like to take a look at the properties of the ChDR emitted by muons, which contaminate the beam, and try to approximate the degree of contamination.

3.2 Theoretical background

Cherenkov Radiation refers to light emitted by an ultrarelativistic charged particle when passing through a dielectric medium [3]. The radiation is named after Pavel Cherenkov, a Soviet physicist, who observed it while working with uranium salt solutions in 1934. According to all known laws of physics there is no way a particle with a rest mass should be able to travel faster than the speed of light in a vacuum. But they can move faster than the speed of light in media other than vacuum. When this happens in the vicinity of a dielectric medium, the ultrarelativistic charged particles emit ChDR if the speed of the particles is greater than the speed of light in that dielectric medium [2]. The atoms of the medium get polarized by the electric field of the ultrarelativistic charged particle, oscillate and thereby emit ChDR [4] at a characteristic Cherenkov angle [2] [3]

$$\theta = \arccos\left(\frac{1}{\beta n}\right) \tag{1}$$

where β is the fraction of the speed of light at which the particle moves $\left(\beta = \frac{v}{c}\right)$. For ultrarelativistic charged particles, β is approximately 1. According to [5] the Cherenkov angle of fused silica ($n = 1.46$) can be estimated with

$$\theta \approx \arccos\left(\frac{1}{1.46}\right) \approx 46.8^{\circ}. \tag{2}$$

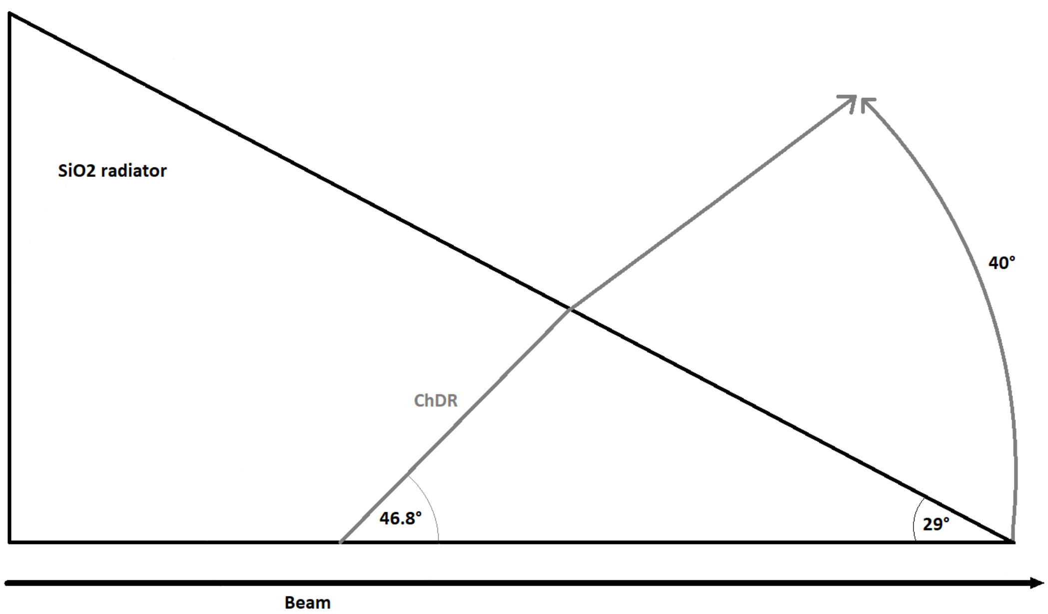

Figure 1: ChDR emission on a fused silica radiator [3]

The light is refracted at the radiator boundary according to Snell's law of refraction (see Figure 2):

$$\frac{\sin(\alpha)}{\sin(\beta)} = \frac{n_2}{n_1} \tag{3}$$

$$\beta = \arcsin\left(\frac{n_2 \sin(\alpha)}{n_1}\right) \tag{4}$$

$$= \arcsin\left(\frac{1.46 \cdot \sin(14.2°)}{1}\right) = 20.987° \tag{5}$$

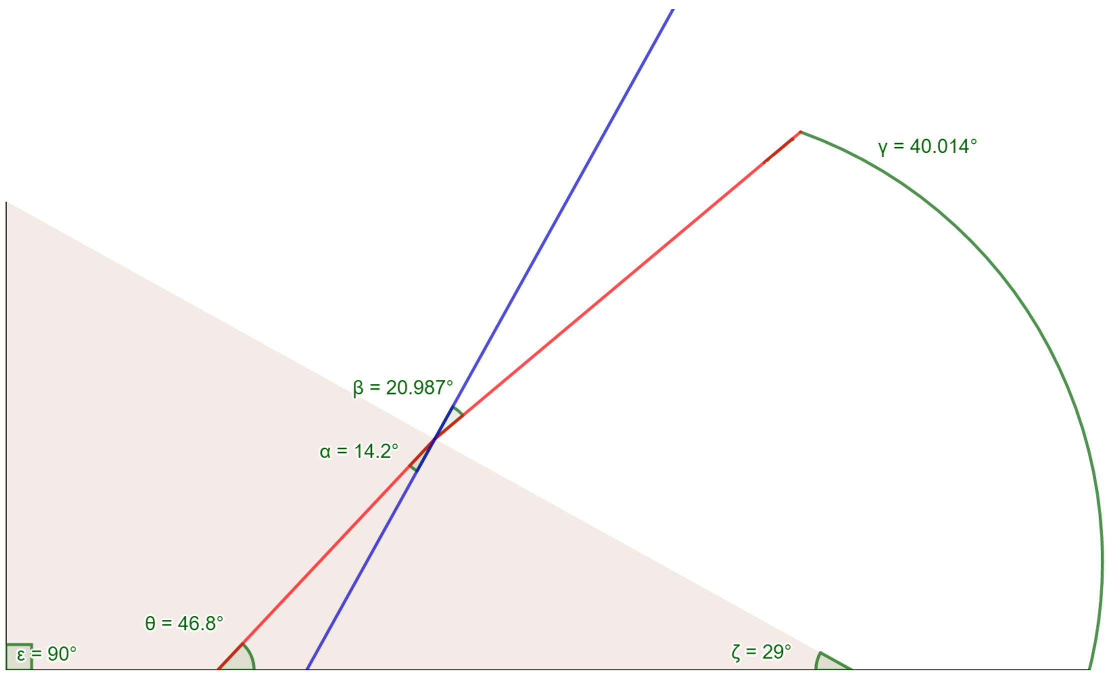

Figure 2: Sketch of the refraction

3.3 Method

First, we want to create a working ChDR-detector for beam diagnostics. Following that, we want to compare the properties of the electron and positron beams and finally search for muon contamination in the particle beams.

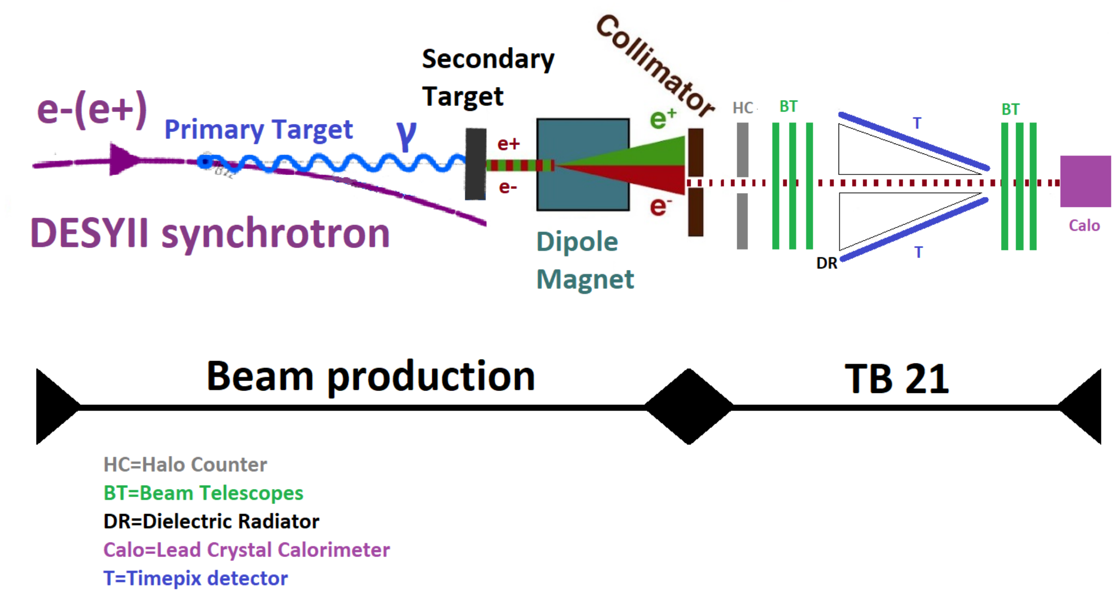

Figure 3: Experimental setup to measure ChDR from electrons and positrons

The particle beam, consisting of either electrons or positrons, leaves the collimator with a well defined position and momentum. Using the Halo counter, we want to measure the scattering of the particles and then track the beam before and after the dielectric radiator, which would enable us to reconstruct the beam path. When travelling through the hollow radiator, the particles should emit ChDR which can be measured with the Timepix detector.

The experiment will probably be affected by the number of available particles per beam pulse at DESY. The light output is about 0.8×10^{-3} photons per charged particle at a distance of 1 mm from a 2 cm long radiator [3]. Therefore, we would conduct the experiments with various particle momenta ranging from approximately 1.5 GeV/c to 2.5 GeV/c to achieve a high particle rate and consequently be able to measure more photons. Finally, we would determine the particle energy with the calorimeter to approximate the amount of energy the particles lost due to the measurement. The setup to estimate the muon contamination is very similar, we would simply include a 10 cm thick iron plate to filter out the electrons or positrons. As muons also emit ChDR, we can estimate the degree of contamination by comparing the measurements.

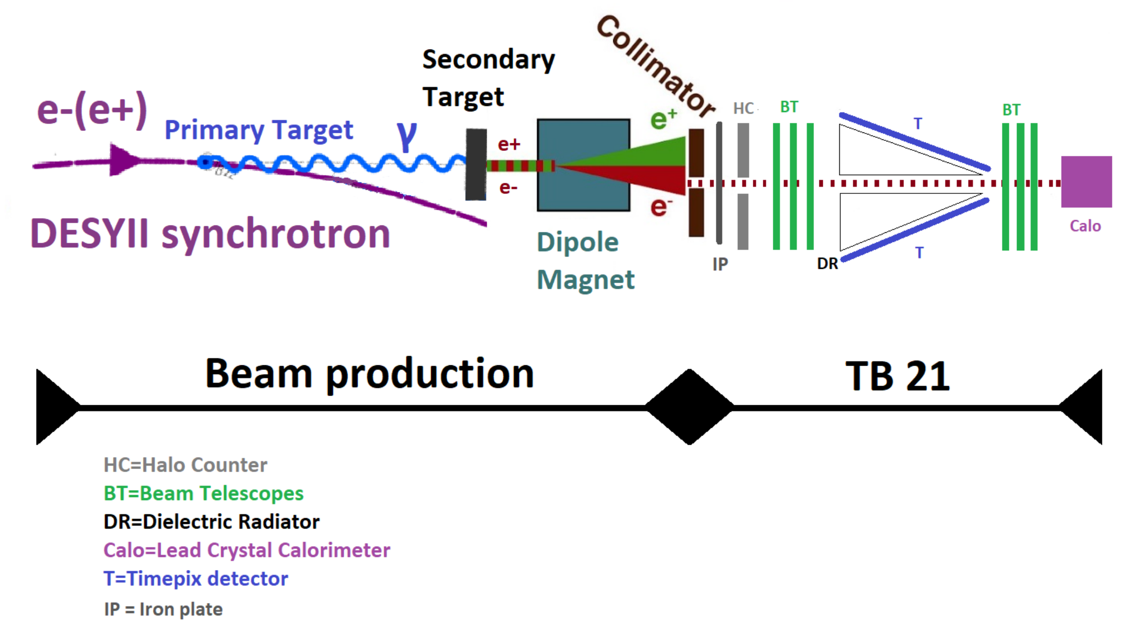

Figure 4: Experimental setup to estimate muon contamination

Since electrons and positrons have similar characteristics apart from opposite charges, we do not expect major differences in the respective ChDR. Our experiment requires a pyramidal radiator (see Figure 5) made of a dielectric material (fused silica), which we would have manufactured.

4 What we hope to take away

We want to gain experience in experimental physics and be able to take research from the classroom to a real-life setup and further our understanding of the underlying physical principals. We hope to get insights into the everyday work in a research organization and gain first experiences that will help us in the future, especially if we decide to pursue a career in experimental research. Additionally, we hope to spark the interest of other students from our school, especially the younger ones, in the vast field of particle physics or maybe even inspire the older ones to participate themselves.

5 Acknowledgements

We would like to thank our teachers Mr. Seidemann and Mr. Irmer for taking us to CERN and BESSY II, sharing their passion for physics with us and making it possible for us to participate. We would also like to thank Dr. Thibaut Lefèvre from CERN for answering our questions.

6 Appendix

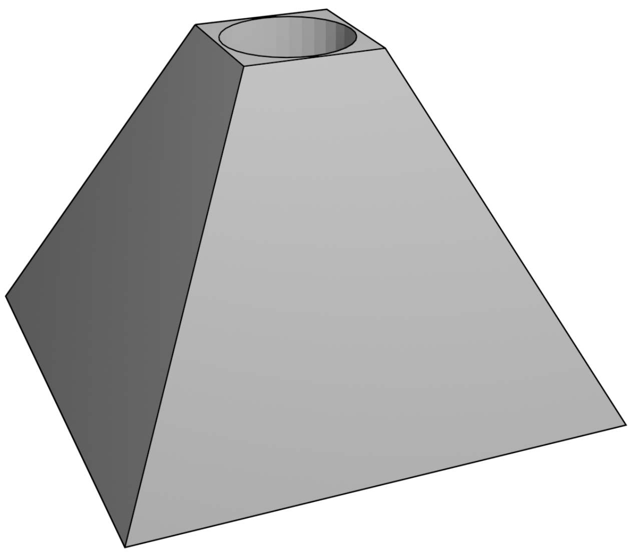

Figure 5: 3D-model of the dielectric radiator (not to scale)

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