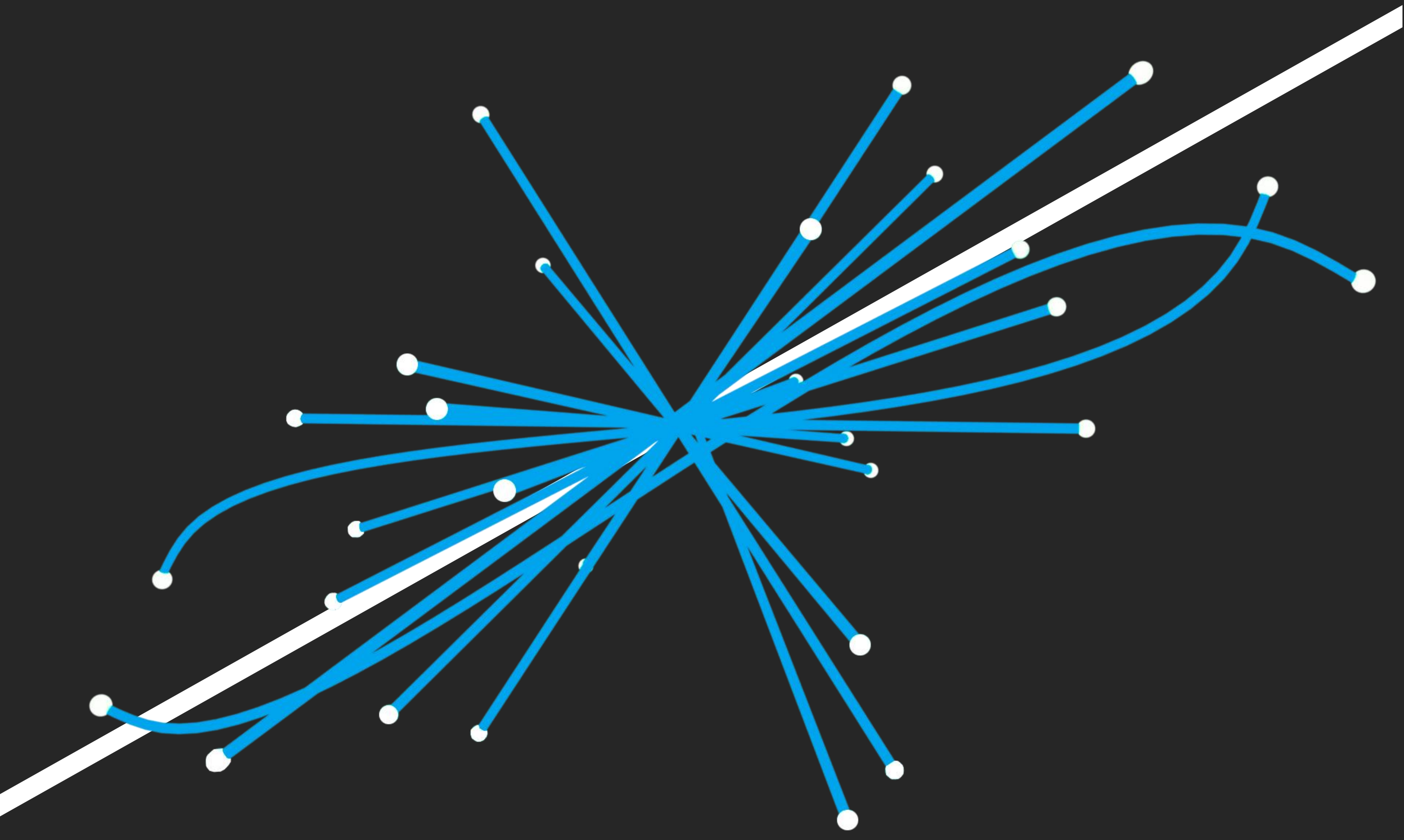

DEFLECTION VERIFICATION

DoesAntimatter

INDEX

OUR EXPERIMENT

AIM:

1. To characterize **deflection of electron and positron beams as a function of the strength of the magnetic field and velocity of the particles** and verify or contrast our theoretical function across various momenta and fields.
2. Alongside the experiment, help in R&D **by quantifying efficiencies and limits of Micromegas, scintillators and MRPCs** and address them in error margins of our experiment.

EXPERIMENT SETUP:

1. We pass the beam through a **scintillator to measure the initial energy** of the incident beam to assist in **velocity verification.**
2. The beam then passes through **2 MRPCs who take accurate time readings** to help in the **calculation of velocity** of the particles.
3. The beam then passes through the **BRM (known field) causing it to bend.**
4. This bend is detected by **an array of Micromegas**.

Method:

$$y = f(B, v)$$

$$dy = \left(\frac{\partial y}{\partial B}\right)_v dB + \left(\frac{\partial y}{\partial v}\right)_B dv \quad \text{—(i)}$$

Calculated experimentally

Keeping one parameter constant to obtain the dependence on the other. Eq(i) will be then be **integrated to give the actual function of y.**
We then compare this with the theoretical function we calculated to get value of y.
This part allows us to distribute the error between the theoretical and the practical output to the detectors involved after careful consideration of where they propagated from.
We will perform the experiment with **both electron and positron beams as we iterate over momenta checkpoints at 0.5,1,3 and 6 GEv/c**, This number may be increased to get more data points if necessary post formulation of the function, to calibrate detectors based on our model

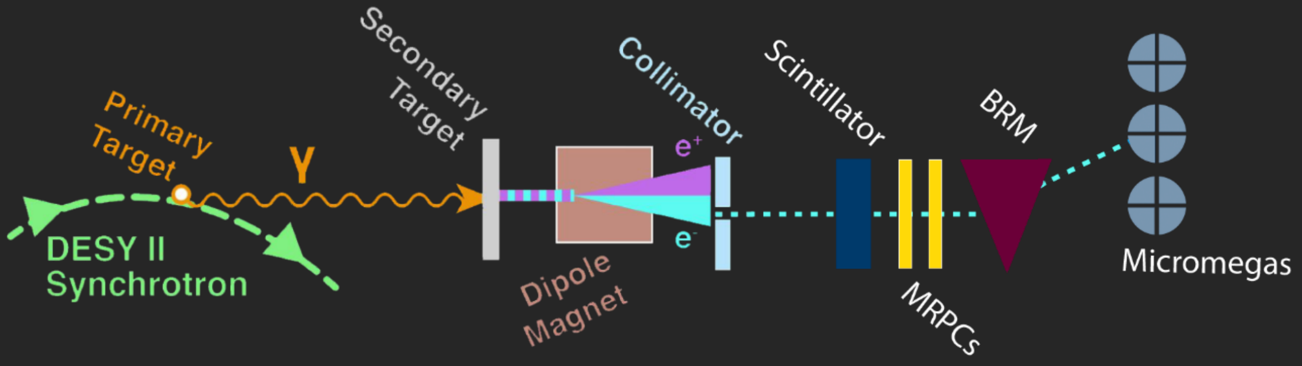

Figure-1: Experiment Setup

Theoretical Function

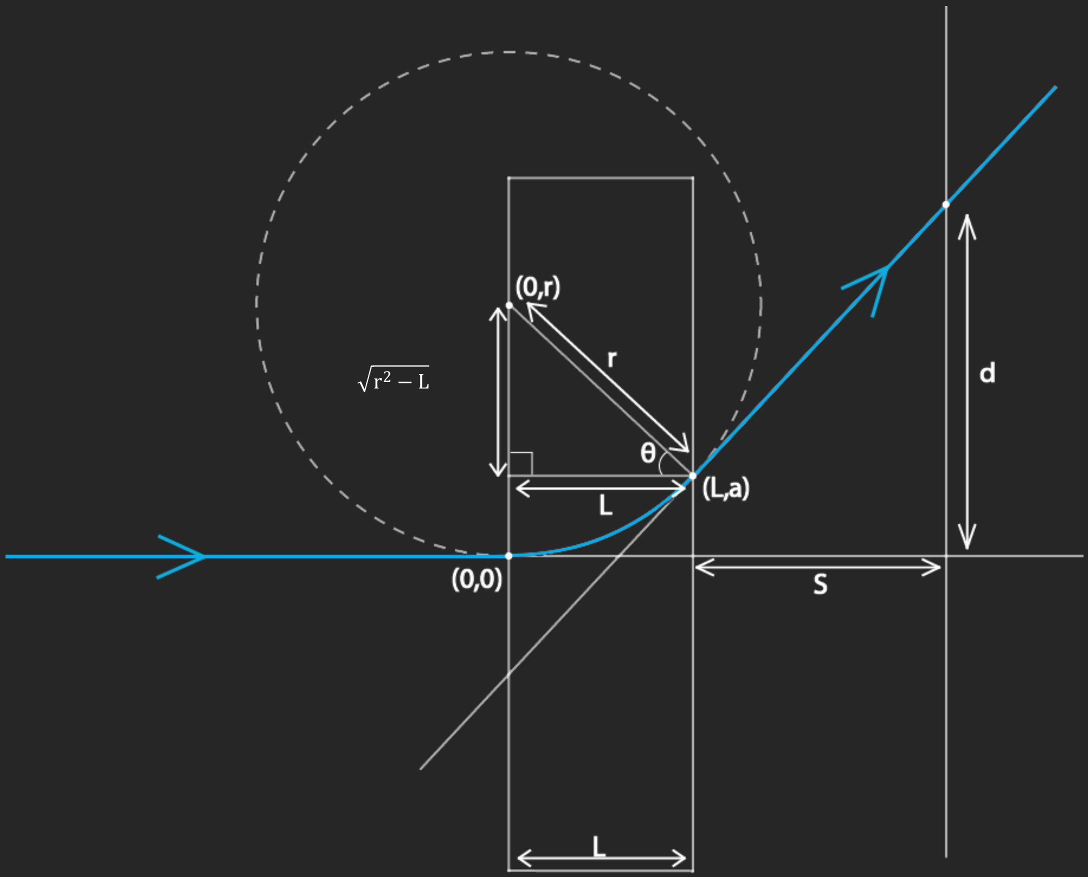

Figure-2: Deflection

The goal is to obtain 'd' (deflection) in terms of 'r' (radius of circle in field), 'L' (length of magnetic field) and 's' (distance in front of which micromega is placed) which are constants.

The beam forms a circle in the magnetic field and exits tangentially when the field ends. Conventional calculation proved to be lengthy, hence we targeted the problem with co-ordinate geometry: the concept being that the equation of tangent at point (L,a) as shown in figure intersected with line **x=s+L would give us the point of detection, whose y coordinate is 'd'.**

Eliminating 'a' with a = r-rsin(θ) we get a in terms of 'r' and 'L' as:

$a = r - \sqrt{r^2 - L^2}$ **—(1)**

Writing the equation of tangent in point slope form at (l,a):

$$y - a = \left(\frac{L}{r - a}\right)(x - L)$$

Plugging value from (1) and x=s+l gives us:

$$d = \left(\frac{L}{\sqrt{r^2 - L^2}}\right)s - \sqrt{r^2 - L^2} + r\text{, where r} = mv/Bq$$ **—(Theoretical Function)**

GRAPHS

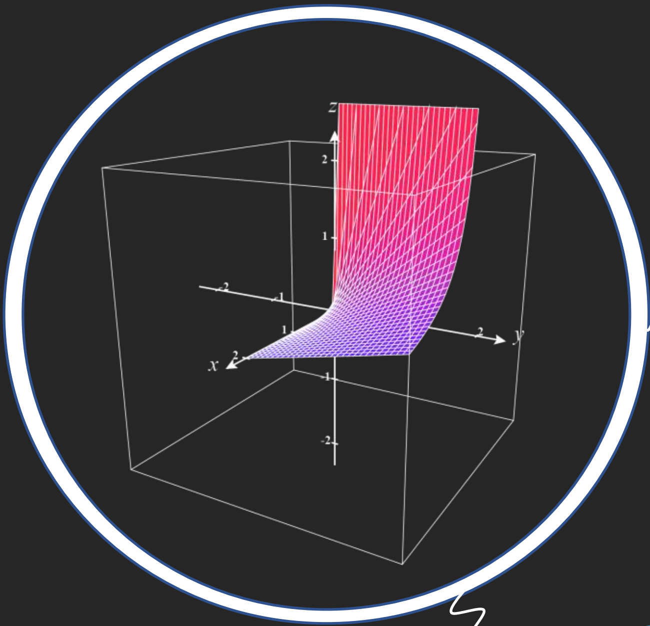

Figure-3: *Graph of 'theoretical function';* ***d = f(v,B),*** *'x' axis corresponds to v, 'y' to B and 'z' to deviation.*

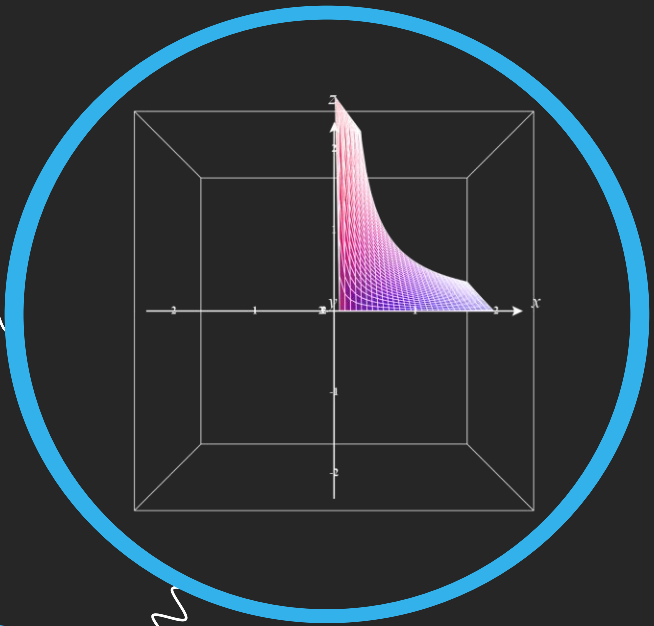

Figure-4: *View from xz (v,d) plane, Clearly we see as velocity increases, deflection decreases. (Radius of deflection increases)*

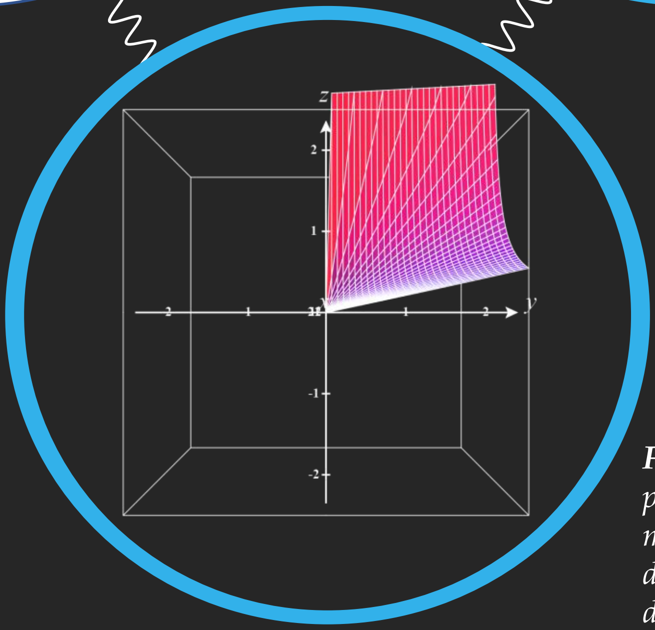

Figure-5: *View from yz (B,d) plane, Clearly we see as magnetic field increases, deflection increases. (Radius decreases)*

The reason behind drawing and comparing graphs is purely driven by the **fundamental zeal** of **science**: Keeping an **unbiased** and **open mind**.

In the occurrence of the event where our theoretical model does not match the practically observed result or we observe significantly different behavior for electrons and positrons, having graphs at our disposal allows us to analyze the exact regions/ranges of a particular parameter where strange behavior or deviation from predictions was observed.

By **re-performing the experiment at the values where we observed a deviation**, we will be able to **strengthen the difference or nullify it**. Thereby giving our experiment **more credibility.**

Distribution Of Error

The resolution of the MRPC of about 100 picoseconds in itself will not be enough to differentiate between velocities of 2 different relativistic momenta. While we can calculate velocity from relativistic momentum by:

$$v = \sqrt{\frac{p^2/m^2}{1 + \frac{p^2/m^2}{c^2}}}$$

We wanted to experimentally verify a close figure of 'v' since our aim involves developing a function of magnetic field and velocity. We have hence employed a scintillator to help gain an **additional figure of velocity** by calculating it from **relativistic energy.**

As a matter of fact, even if our experiment does not showcase a difference between electrons and positrons, we still have developed a very effective **tool to now be able to measure and visualize the difference in velocities near the speed of light**.

Our calculations predict that significant deviation will be observed with increments in relativistic velocity. These velocities cannot be distinguished with MRPCs.

Similarly, we can also use our experiment to build a function to obtain energy from a scintillator by **reverse engineering our experiment and calibrate it.**

Velocity (m/s)	Radius (m)	Deflection at 2m in front of BRM *
299792301	1.66	1.844 m
299792419	3.33	0.783 m
299792448	6.67	0.378 m
299792453	10.00	0.251 m
299792456	20.01	0.125 m

*Note:
Above results assume length of magnetic field of BRM to be of 1 meter.
Our formula for deflection considers change in 'L' (length of magnetic field) and can be incorporated later for better accuracy.

- By improving accuracy of measurement of deflection, one can be even more confident about impinging velocity.

Why We Want To Go To DESYII

When we first heard about Beamline For Schools, most of us were daunted because all we knew about particle physics came from pop science and introductory books that didn't get far into the details, and now, we were being asked to design an experiment. But a chance to actually get to perform it at DESYII, interacting with people who smash and toss around particles for a living, it was perhaps the most exciting opportunity we had ever been provided.

It compelled us to utilize every minute away from our classes, every minute during all our commute, or even on the dinner table, on researching and trying to figure out more of how particle physics worked. Even though we found out about the competition only a month before submission, it only served as an impetus to try harder and make the most of the time we had. And with a team full of aspiring researchers, it never even felt like work. Every time we understood something slightly better, the rush it gave us kept us turning every conversation into a conversation about the contest.

To interact with some of the scientific minds of our time and to have them refine and carry out an experiment we designed may be every teenage physics enthusiast's dream. We would only hope to be able to perpetuate this exhilaration in our peers. This extraordinary learning opportunity would undoubtedly leave a significant mark in our future ambitions, providing us with a better understanding of what it is like to be a researcher, as well as a better appreciation of the subject.

Our Team

Vaibhav Malik

Nishchay Sinha

Sidak Taneja

Kushagra Sharma

Jaskeerat Singh

Manaswinee Gupta

Kreetik Thakur

“

No matter how many times the results of experiments agree with some theory, you can never be sure that the next time the result will not contradict the theory.

”

-Stephen Hawking

ACKNOWLEDGEMENTS

We are extremely grateful to Beamline4Schools for not only such a great learning opportunity but also the contact resources which were very responsive and helpful throughout. During these exchanges, we were amazed by the number of factors physicists think about when designing an experiment. It was then hit the ideology physicists carry with every experiment. The hope and passion as carried by the above quote.

This project simply wouldn’t have existed if it weren’t for our terrific physics teachers. They guided us enough so we knew how to approach the problem, while trusting us to think for ourselves and come up with our own ideas. Their constant support kept us going right till the very end.

Lastly, we’d like to thank our parents who allowed us to push our bedtimes just a little(a lot) further.

Bibliography :

https://beamlineforschools.cern/
https://www.wolframalpha.com/
https://www.youtube.com/playlist?list=PL93B3DDC89C085C1C
https://en.wikipedia.org/wiki/Mass_in_special_relativity
https://en.wikipedia.org/wiki/Synchrotron_radiation
https://www.monroecc.edu/faculty/paulseeburger/calcnsf/CalcPlot3D/
https://en.wikipedia.org/wiki/Scintillator
https://www.desmos.com/