ST. Joseph's College (autonomous)

Final year project

VERIFICATION OF BETHE – BLOCH FORMULA USING GEANT4

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March 1, 2018

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Certificate

This is to certify that the project entitled "Verification of Bethe - Bloch formula using Geant4" is a bona fide work carried out by ***Mr. JOBISH JOSE***, student of St. Joseph's College (autonomous), at Indian Institute of Science in partial fulfilment of the requirements for the degree of Masters in Physics in the year 2017-2018. This project report has been approved by as it satisfies the academic requirement of the project work prescribed for MSc. in Physics.

Dr.Sandiago
Head of the Department
Department of Physics

Place:
Date:

Centre for High Energy Physics

(INDIAN INSTITUTE OF SCIENCE)

Certificate

This is to certify that the project entitled ”Verification of Bethe – Bloch formula using Geant4.” is a bona fide work carried out by ***Mr JOBISH JOSE***, in partial fulfilment of the requirements for the degree of Masters in Physics in the year 2017-2018 at St. Joseph’s College (autonomous) is an authentic work carried out by her under my supervision and guidance. To the best of my knowledge, the matter embodied in the project has not been submitted to any university/Institute for the award of any Degree.

Dr. Jyothsna Rani Komaragiri
Centre for High Energy Physics
Indian Institute of Science

Place:
Date:

Declaration

I do hereby declare that review report of the proposed project entitled "VERIFICATION OF BETHE - BLOCH FORMULA USING GEANT4" to be carried out in the final semester for the partial fulfilment of the requirements of the award of degree of Master of Science (M.Sc.) in Physics is prepared by me. To the best of my knowledge I didn't breach any copyright act intentionally.

JOBISH JOSE

March 6th 2018

ABSTRACT

The stopping power in heavy charged particles is an important parameter in determining the energy loss. In this project I calculate the stopping power of a proton and an electron in lead and in water and verify the Bethe – Bloch formula which relates the incident energy of the incoming particles with stopping power. This is done through an object oriented toolkit named GEANT4 which is developed for the virtual study of high energy particles. The results of stopping power of electrons and protons and its applications are all discussed in detail.

ACKNOWLEDGEMENT

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CHAPTER 1: INTRODUCTION

1.1. : BACKGROUND AND MOTIVATION

Particle physics is the branch of physics that studies the nature of the particles that constitute matter and radiation. It tries to explain the behaviour of the smallest particles from the quantum realm and tries to understand the physics at play at the subatomic level.

Discovery of radioactivity was the stepping stone to the discovery of electrons, protons and later neutrons. Several nuclear models came later to put everything into picture like the plum pudding model and Rutherford's model with each one trying to rid itself of the deficiencies of the other.

Further experiments and studies led to the Bohr's atomic model. Studies showed that electrostatic force could not be the reason for holding the nucleons together, therefore there had to be a different kind of force that bound the nucleus - the Strong force and a different force that led to beta decay - the Weak force. Physicists added the strong force and the weak force to the fundamental forces which only had the gravitational force and the electrostatic force at that time.

The picture of indivisible atom was relevantly replaced by the smaller entities : electrons, protons and neutrons. Added to this were the photons and neutrinos. Technological developments in 1960s enabled that high energy beams of particles could be produced in the laboratories. As a consequence, a wide range of controlled scattering experiments could be performed and the greater use of computers meant that sophisticated analysis techniques could be developed to handle the huge data that were being produced. This led to the detection of large number of unstable particles with shorter lifetime.

The best theory of elementary particles we have at present is called the standard model. This aims to explain all the phenomena of particle physics, except those due to gravity, in terms of the properties and interactions of a small number of elementary (or fundamental) particles, which are now defined as being point-like, without internal structure or excited states.

To explore the structure of nuclei (nuclear physics) or hadrons (particle physics) requires projectiles whose wavelengths are at least as small as the effective radii of the nuclei or hadrons. The largest collider currently is the Large Hadron Collider (LHC), which is at CERN, Geneva, Switzerland. This is a massive pp accelerator of circumference 27 km, with each beam having energy of 7 TeV.

Particle physics made giant strides in the 20^{th} century thanks to the widened understanding of quantum mechanics. Throughout the 1950s and 1960s, a wide variety of particles were found in high energy collisions of particles in labs around the world. These particles were explained as combinations of a small number of even more fundamental particles. The standard model is currently the best theory that explains the fundamental particles and fields and the interactions between them. Thus, modern particle physics generally investigates the Standard Model and its many particles which can give us an idea into the longest standing questions that has haunted the human race from the beginning

1.2 : THE STANDARD MODEL

The Standard model is a theory that classifies all elementary particles in nature as well as explaining the three fundamental forces in nature out of the four except for gravitation. It was developed in stages throughout the latter half of the 20th century, through the work of many scientists around the world. The model was accepted worldwide only after the experimental confirmation of the existence of quarks. Since then, confirmation of the top quark (1995), the tau neutrino (2000), and the Higgs boson (2012) have added further credence to the Standard Model. In addition, the Standard Model has predicted various properties of weak neutral currents and the W and Z bosons with great accuracy.

The Standard Model is believed to be theoretically self-consistent. It has made some exceptional predictions that were later confirmed through the use of high energy particle colliders. But it does have its own deficiencies so far, the model does not contain any viable dark matter particles that possess all of the required properties deduced from observational cosmology. It also does not incorporate neutrino oscillations and their non-zero masses. Physicists have so far been unable to absorb the theory of relativity into its structure. But it still remains the best model to date to describe subatomic particles and the fundamental interactions between them

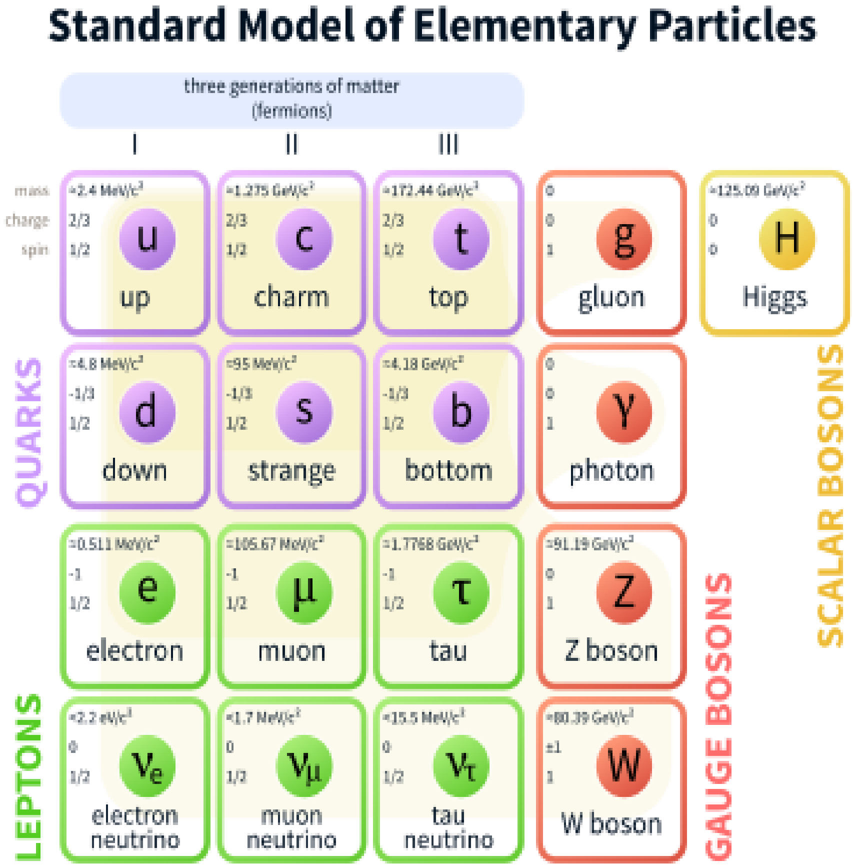


Figure 1.1 :figure depicting the most fundamental particles in the standard model.[1]

The Standard Model includes 12 elementary particles of spin ½, known as fermions and they obey the Pauli's exclusion principle. Each fermion has a corresponding antiparticle.

The fermions of the Standard Model are classified according to how they interact. Fermions comprise of six quarks (up, down, charm, strange, top, bottom), and six leptons (electron, electron neutrino, muon, muon neutrino, tau, tau neutrino). Pairs from each classification are grouped together to form a generation, and in a generation all the particles have the same properties except for mass which increases from the first to the third generations. The difference in mass within a generation creates subsequent difference in physical properties.

The defining property of the quarks is that they carry colour charge, and hence interact via the strong interaction. A phenomenon called colour confinement results in quarks being very strongly bound to one another, forming colour-neutral composite particles (hadrons) containing either a quark and an anti-quark (mesons) or three quarks (baryons). The proton and neutron are the two baryons having the smallest mass. Quarks also carry electric charge and weak isospin. Hence they interact with other fermions both electromagnetically and via the weak interaction. The remaining six fermions do not carry colour charge and are called leptons. The three neutrinos do not carry electric charge so their motion is directly influenced only by the weak nuclear force, for this reason these particles are very hard to detect. However, the electron, muon, and tau all interact electromagnetically because of their electric charges.

Each member of a generation has greater mass than the corresponding particles of lower generations. The first-generation charged particles do not decay, hence all ordinary (baryonic) matter is made of such particles. All atoms consist of electrons orbiting around atomic nuclei. All nuclei are constituted of up and down quarks. Second- and third-generation charged particles, on the other hand, decay with very short half-lives and are observed only in very high-energy environments.

In the Standard Model, gauge bosons are defined as force carriers that mediate the strong, weak, and electromagnetic fundamental interactions.

Interactions in physics are the ways that particles influence other particles. At a macroscopic level, electromagnetism allows particles to interact with one another via electric and magnetic fields, and in gravitation particles with mass to attract one another obeying Einstein's theory of general relativity. The standard model explains this through the theory of gauge bosons. When a force-mediating particle is exchanged, there is a field and a force produced between them.. The Feynman diagram calculations, which are a graphical representation of the perturbation theory approximation, invoke "force mediating particles", and when applied to analyze high-energy scattering experiments are in reasonable agreement with the data. However, perturbation theory (and with it the concept of a "force-mediating particle") fails in other situations.

The gauge bosons of the Standard Model all have spin of 1, this is what makes them bosons. Bosons do not have a theoretical limit on their spatial density (number per volume).This is because they do not obey the Fermi – Dirac statistics. Another important feature of the gauge bosons is that the lighter they are, the rangier the force they bring about. The different types of gauge bosons are described below.

- Photons are the gauge bosons for electro – magnetic force. They are described by classical and quantum electrodynamics
- The $W+$,$W-$, and Z gauge bosons mediate the weak interactions between particles of different flavours (all quarks and leptons). The $W\pm$ carries an electric charge of $+1$ and -1 and can undergo electromagnetic interaction. The Z boson does not carry any charge. These three gauge bosons along with the photons are grouped together, as collectively mediating the electroweak interaction.
- The eight gluons produce the strong interactions between quarks which are colour charged particles. Gluons are massless. The eightfold multiplicity of gluons is labelled by a combination of colour and anti-colour charge (e.g. red–anti green). Because the gluons have an effective colour charge, they can also interact among themselves. The gluons and their interactions are described by the theory of quantum chromodynamics.[1]

1.3: PARTICLE ACCELERATORS

A particle accelerator is a machine that uses electromagnetic fields to propel charged particles to nearly the speed of light and contain them in well-defined beams. Large accelerators are used in particle physics as colliders (e.g., the LHC at CERN, KEKB at KEK in Japan, RHIC at Brookhaven National Laboratory, and Tevatron at Fermilab), or as synchrotron light sources for the study of condensed matter physics. Smaller particle accelerators are used in a wide variety of applications including radioisotope production for medical diagnostics, ion implanters for manufacture of semiconductors etc..

Particle accelerators are used in collider experiments make basic inquiries into the dynamics and structure of matter, space, and time, we use these colliders at the highest possible energies to probe deeper into the atom. The particles can be accelerated to energies of many GeVs. Since isolated quarks are experimentally unavailable due to colour confinement, the simplest available experiments involve the interactions of, first, leptons with each other, and second, of leptons with nucleons, which are composed of quarks and gluons. To study the collisions of quarks with each other, scientists resort to collisions of nucleons, which at high energy may be usefully considered as essentially 2-body interactions of the quarks and gluons of which they are composed.[2]

The largest and highest energy particle accelerator used for elementary particle physics is the Large Hadron Collider (LHC) at CERN, Switzerland. It has been operational since 2009. It is much more energetically efficient to use colliders in which we have two sets of particles colliding with each other head on tha having a stationary target. This has got to do with the fact that it becomes harder and harder to accelerate particles as their velocity approaches the speed of light owing to special theory of relativity.

1.4 : THE CMS PROJECT

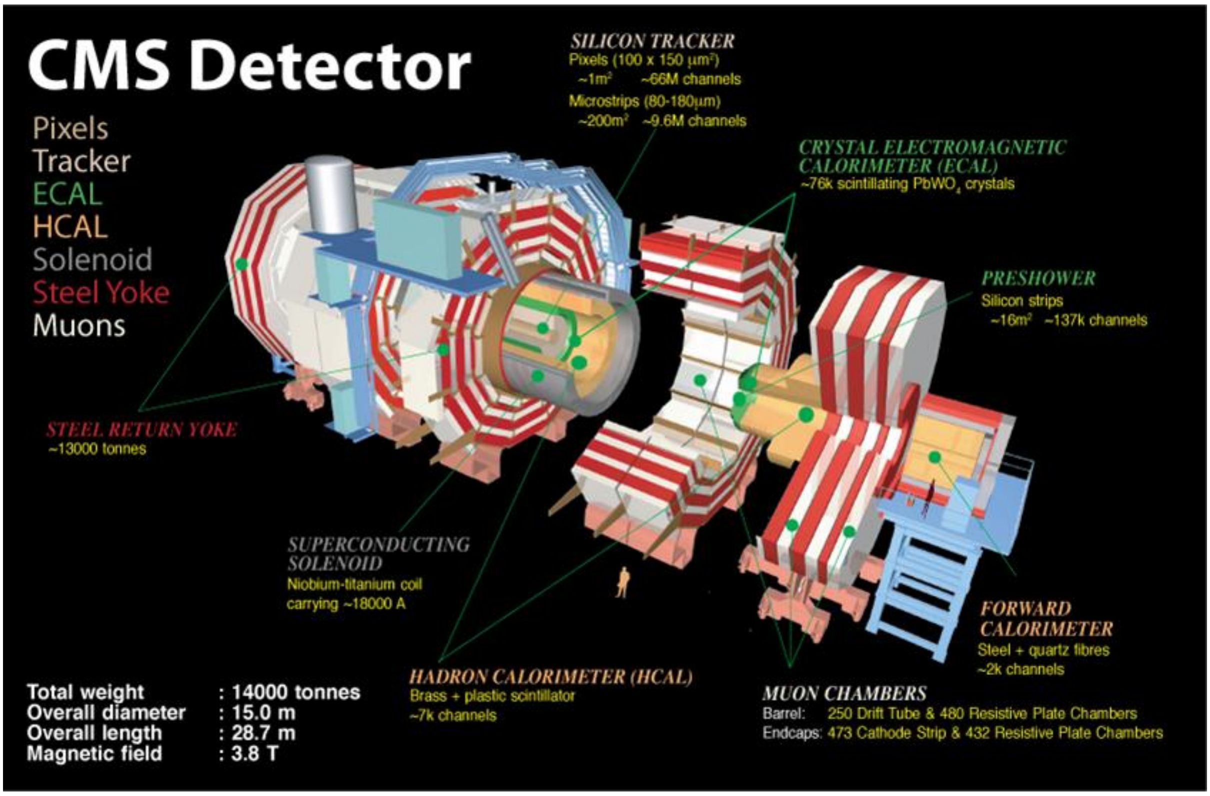


Fig : CMS DETECTOR[3]

The **Compact Muon Solenoid** experiment is a large particle physics detector built on the Large Hadron Collider.. The goal of CMS experiment is to investigate a wide range of physics, including the search for the Higgs boson, extra dimensions, and particles that could make up dark matter.

CMS is designed as a detector, used to study the aspects of pp collisions at 0.9-13 TeV.

Structure :

The CMS detector is built around a huge solenoid magnet. This takes the form of a cylindrical coil of superconducting cable that generates a magnetic field of 4 teslas, about 100 000 times that of the Earth. The magnetic field is confined by a steel 'yoke' that forms the bulk of the detector's weight of 12500 tonnes. An unusual feature of the CMS detector is that instead of being built in-situ underground, like the other giant detectors of the LHC experiments, it was constructed on the surface, before being lowered underground in 15 sections and reassembled.

The CMS detector contains subsystems which are designed to measure the energy and momentum of photons, electrons, muons, and other products of the collisions. The innermost layer is a silicon-based tracker. Surrounding it is a scintillating crystal electromagnetic calorimeter, which is itself surrounded with a sampling calorimeter for hadrons. The tracker and the calorimetry are compact enough to fit inside the CMS Solenoid which generates a powerful magnetic field of 3.8 T. Outside the magnet are the large muon the detectors, which are inside the return yoke of the magnet.

The layers of CMS can be described below

1. **The interaction point** : This is the point in the centre of the detector at which pp collisions occur between the two counter-rotating beams of the LHC
2. **Layer 1 – The tracker** : Momentum of particles is crucial in helping us to build up a picture of events at the heart of the collision. One method to calculate the momentum of a particle is to track its path through a magnetic field; the more curved the path, the less momentum the particle had. The CMS tracker records the paths taken by charged particles by finding their positions at a number of key points.
3. **Layer 2 – The Electromagnetic Calorimeter :** The Electromagnetic Calorimeter (ECAL) is designed to measure with high accuracy the energies of electrons and photons**.**
4. **Layer 3 – The Hadronic calorimeter:** The Hadron Calorimeter (HCAL) measures the energy of hadrons, particles made of quarks and gluons (for example protons, neutrons, pions and kaons). Additionally it provides indirect measurement of the presence of non-interacting, uncharged particles such as neutrinos.
5. **Layer 4 – The magnet :** The CMS magnet is the central device around which the experiment is built, with a 4 Tesla magnetic field that is 100,000 times stronger than the Earth's. CMS has a large solenoid magnet. This allows the charge/mass ratio of particles to be determined from the curved track that they follow in the magnetic field.
6. **Layer 5 – The muon detectors and the return yoke :** To identify muons and measure their momenta, CMS uses three types of detector: drift tubes (DT), cathode strip chambers (CSC) and resistive plate chambers (RPC). The DTs are used for precise trajectory measurements in the central *barrel* region, while the CSCs are used in the *end caps*. The RPCs provide a fast signal when a muon passes through the muon detector, and are installed in both the barrel and the end caps.[4]

CHAPTER 2 : LITERATURE SURVEY

2.1 : LITERATURE REVIEW AND BACKGROUND WORK

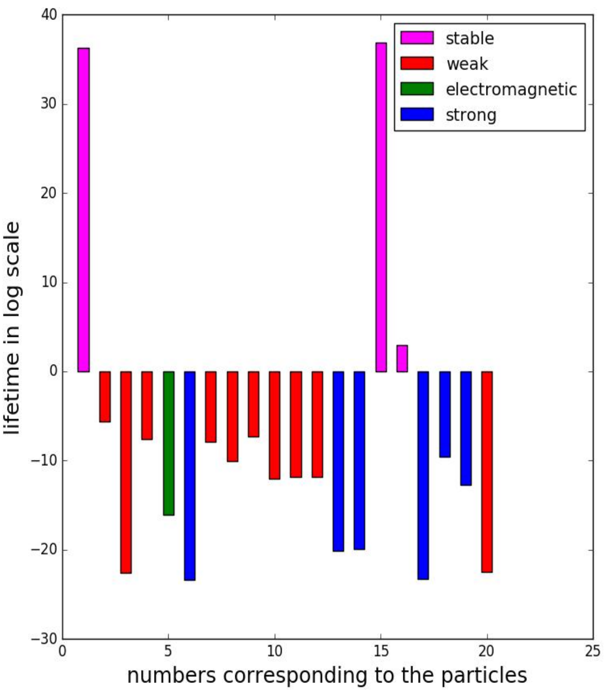
References like Introduction to Elementary Particles - 2nd edition by David Griffiths, NPP-lectures-Aug-Sep-Oct.pdf by Dr. Jyothsna Rani Komaragiri was referred.

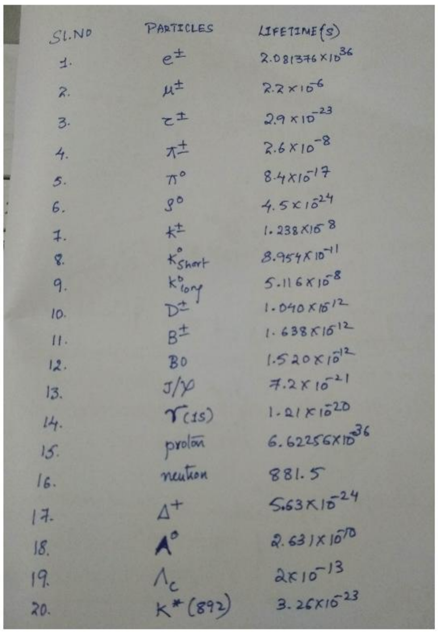
2.1.1 : STABILITY OF PARTICLES

For a selected list of particles with known mass and Lifetimes, its momenta were varied as p = 1GeV/c, p =10GeV/c and p = 100Gev/c . The distance travelled by those particles before they decayed was calculated using the relativistic equation for distance travelled. So based on these calculations, with the detector kept fixed at a particular distance, it is possible to predict whether a particle would be stable enough to reach the detector

Figure 2.1 shows the list of particles that were studied. It was also colour coded according to the type of interactions the particles undergo.

Conclusion : As expected only the protons, neutrons and electrons were stable.





Sl.NO	PARTICLES	LIFETIME(s)
1.	$e^{\pm}$	2.081376×10^{36}
2.	$\mu^{\pm}$	2.2×10^{-6}
3.	$\tau^{\pm}$	2.9×10^{-23}
4.	$\pi^{\pm}$	2.6×10^{-8}
5.	π^{0}	8.4×10^{-17}
6.	ρ^{0}	4.5×10^{-24}
7.	$K^{\pm}$	1.238×10^{-8}
8.	K^{0}_{Short}	8.954×10^{-11}
9.	K^{0}_{long}	5.116×10^{-8}
10.	$D^{\pm}$	1.040×10^{-12}
11.	$B^{\pm}$	1.638×10^{-12}
12.	B0	1.520×10^{-12}
13.	J/ψ	7.2×10^{-21}
14.	$\Upsilon(1S)$	1.21×10^{-20}
15.	proton	6.62256×10^{36}
16.	neutron	881.5
17.	Δ^{+}	5.63×10^{-24}
18.	Λ^{0}	2.631×10^{-10}
19.	Λ_c	2×10^{-13}
20.	$K^{*}(892)$	3.26×10^{-23}

Figure 2.1: A plot depicting stability of particles, where the particles are numbered on the x-axis. The particle corresponding to each number is mentioned on to the right

2.1.2 : MASS OF THE PARENT PARTICLE

Each pp collision produced a certain number of following particles:

1. Jets
2. Muons
3. Electrons
4. Photons
5. MET- the missing transverse energy

The relativistic equation to find rest mass is given by

$$M_0 = \sqrt{(E^2 - P^2)}.$$

Where E is the total energy of the particle and P is the momentum

And also $P^2 = p_x^2 + p_y^2 + p_z^2$,where p_x , p_y ,p_z are the momenta in x, y, z directions respectively

These particles further decay. A data set detected by the CMS detector, LHC was analysed. The data consisted of energy E and px, py, pz - momentum in x, y and z directions respectively for each particle in every collision event. Let us say, a certain collision produced 5 jets, 2 muons, 0 electrons and 1 photon. Then to know the mass of the particle that decayed to 2 muons, one should add the px for muon1 and muon2 to get total px. Similarly calculate py, pz and E. Using the relativistic equation calculate the mass. The value obtained is the invariant mass of the particle that decayed to give 2 muons. So to calculate the mass of the particle that decayed to give the data under study, similar set of calculations was done and the peak in the plot shows the invariant mass of the parent particle.

Conclusion: The mass obtained matched the theoretical value predicted for the muon mass and this confirms the formation of muons during proton-proton collision.

2.2 : INFERENCES DRAWN FROM LITERATURE REVIEW

The collider physics experiments are very useful in recreating the environment which will in turn create the paricles that were produced moments after the Big Bang. The decay products obtained can be reconstructed back to know the parent particles.

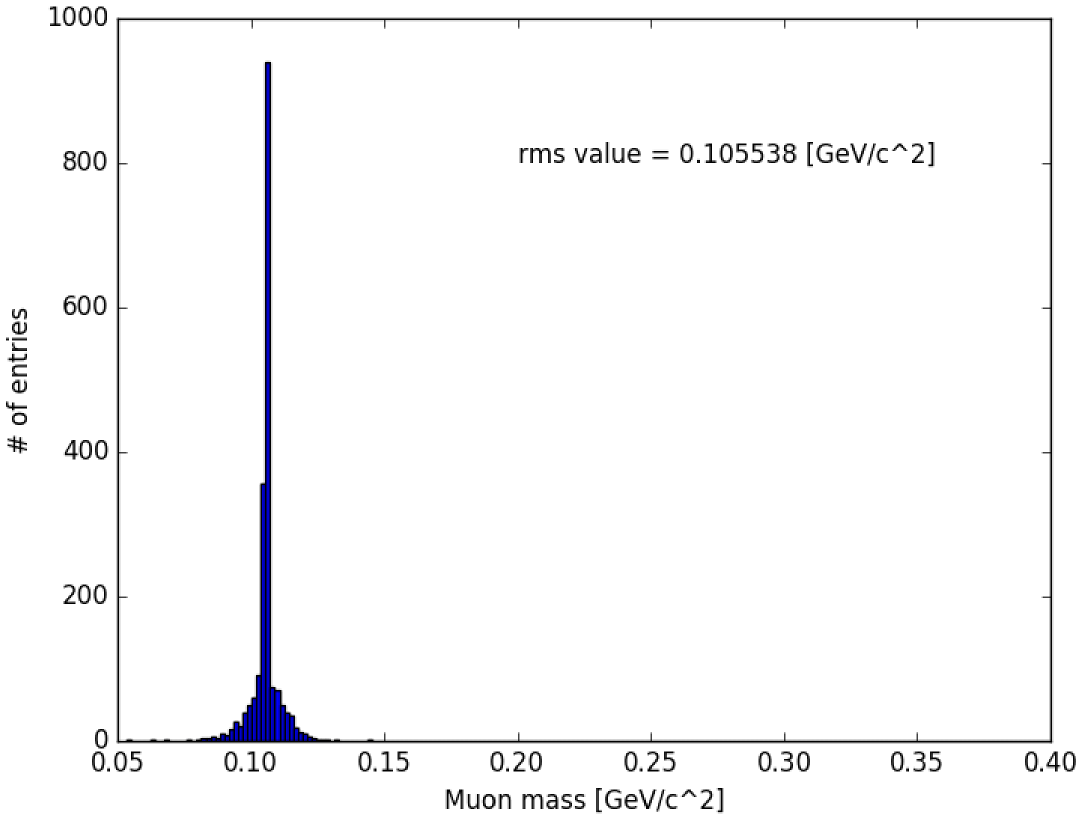


Figure 2.2: Invariant mass

CHAPTER 3: PROBLEM FORMULATION AND PROPOSED WORK

3.1 INTRODUCTION

Experimental setups for carrying out scattering experiments are of two types :

1. Fixed target - A beam of particles strike the particles at rest.
2. Colliding beams - Two counter rotating beam particles strike each other head on.

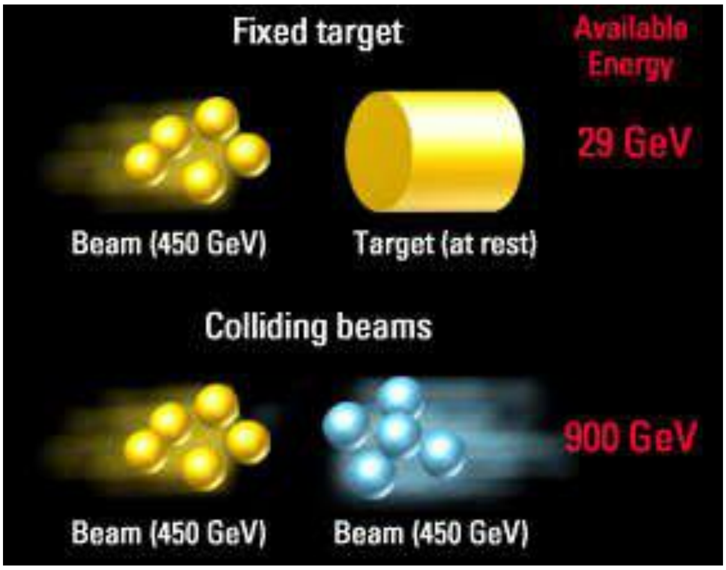


Figure 3.1: fixed target vs colliding beams

Two standard reference frames, corresponding to each of these setups are:

1. Lab frame - The coordinate system in which the beam particles are moving and the target is at rest.

2. Centre of Mass (CoM) frame - The coordinate system in which the net momentum is zero; the beam and the target particle move with equal and opposite momenta.

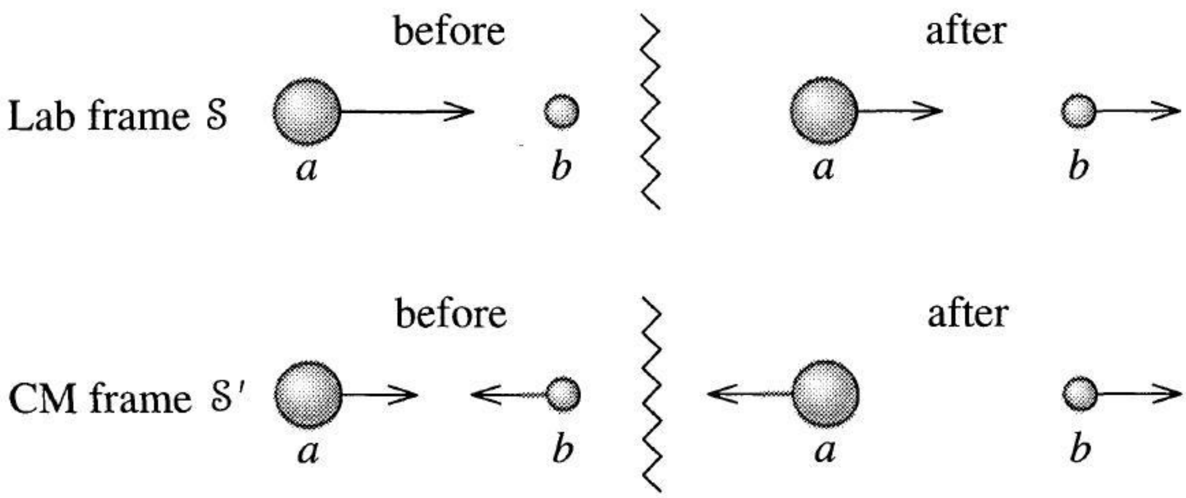


Figure 3.2: Schematic representation of Centre of Mass frame and lab frame

Variables Used :

1. Transverse Momentum - It is the momentum along the transverse plane.

2. Rapidity - Rapidity can be defined as the hyperbolic angle that differentiates two frames of reference in relative motion, each frame being associated with distance and time coordinates.[9]

3. Pseudo-rapidity - spatial coordinate describing the angle of a particle relative to the beam axis. It is defined as

$$\eta = -\ln [\tan(\Theta/2)]$$

Where η is pseudo rapidity and Θ is the angle between the particle three momentum and the positive direction of the beam axis.[8]

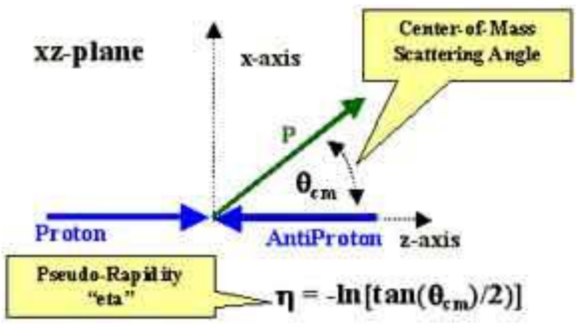


Figure 3.3: Pseudo-rapidity

4. Phi - We take positive z-axis along the incident beam of proton direction. phi is the azimuthal angle with respect to this.

3.2 : BETHE – BLOCH FORMULA

The **Bethe - Bloch formula** describes the mean energy loss per distance suffered by charged particles when they travel through matter. This is also known as the stopping power of the material. The energy loss is different for electrons due to their indistinguishability and small size which requires relativistic corrections. This is because their rest mass is so very low that even small energies imparted to the electrons impart very high kinetic energies, and they also suffer much larger losses by Bremsstrahlung, terms must be added to account for this. The charged particles while travelling through matter lose energy, and this energy is absorbed by the atoms of the material through which these atoms are either ionized or transformed into an excited state. This drains the energy the kinetic energy of the incoming high velocity charged particle. The bethe - bloch formula for relativistic particles is given by

$$-\frac{dE}{dx} = 2\pi N_a r_e^2 m_e c^2 \rho \frac{Z}{A} \frac{z^2}{\beta^2} \left[\ln \left(\frac{2 m_e \gamma^2 v^2 W_{max}}{I^2} \right) - 2\beta^2 \right].$$

Fig 3.2.1 – Bethe – bloch equation

Where **β = v/c.**

C = speed of light

V = velocity of particle

E = electronic charge

Z = atomic number of absorbing material

z = charge of incident particle

þ = density of the absorbing material

N_A = Avogadro number

M_e = mass of electron

n = electron density (number of electrons per unit volume)

I = mean excitation potential

A = mass number

W_{max} = maximum energy transfer in a single collision

R_e = classical electron radius

CHAPTER 4 : METHODOLOGY

4.1 : INTRODUCTION TO GEANT4

GEANT4 (GEometry ANd Tracking) is a soft ware used for the simulation of passage of particles through matter. Its development, maintenance and user support are taken care by the international Geant4 Collaboration. The main application of the platform is in high energy physics .But it is also used in many other fields including medical field, space physics, detector physics etc... The software is used by a number of research projects around the world. One of the aims of this project was to get myself familiar with the detector physics using the geant4 toolkit .Another task that was given was to verify the Bethe function by taking advantages of the functionalities of the geant4 toolkit. The first step taken in pursuit of these goals was trying to understand how the geant4 toolkit worked and using it to build detectors of a certain geometry.

4.2 : SETTING THE DETECTOR GEOMETRY

The detector geometry is defined with the help of geant4. In order to simplify the programming part, a working simulation is provided as a starting point. The code that is provided is edited according to the situation. The material that we need for the construction is obtained from the material lists in geant4 toolkit. The building of the geometry is composed of different definitions: solids, logical volumes and physical volumes. On the top, there is a special volume, in which all the others are placed (world volume). As the material, the geometry is defined in ExN01DetectorConstruction.cc

. First, a solid has to be defined. This is just an abstract geometrical object. Then, a solid and a material are used to create a logical volume. A logical volume can be thought of the idea of a 1 cm3 cube. Finally, to create an actual physical volume, one has to create a placement using the logical volume and a vector indicating the point in space where its center of mass should be with respect to its mother volume, Which is the volume that encompass it. A logical volume can be placed multiple times, each time generating a different physical volume. Every volume we create must be inside an all encompassing volume called the world volume. The code is designed in a way that there is no overlapping between the logical volumes.

When running, the simulation has to know what are the rules that will apply and which particles can be generated. This is done in ExN01PhysicsList.cc.In this part all the particles and physics processes are defined. These are called during the run action. After familiarising with how the geometry works, the next task was to verify Bethe formula for stopping power.

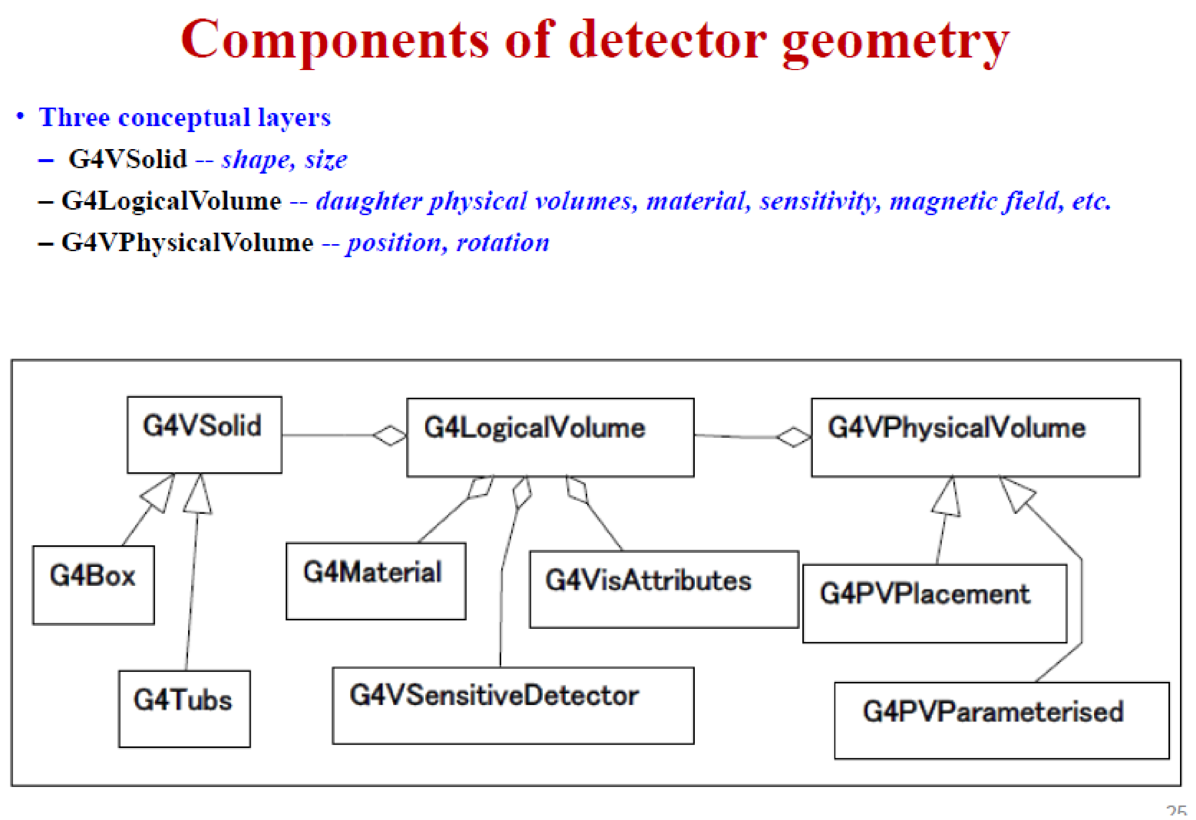


Figure 4.2.1 – geant4 overview[6]

Here is a brief overview of how the detector geometry is defined. The solid is created first. This solid is converted into a logical volume by defining the material, the magnetic field, and the sensitivity of the material etc....Finally the logical volume is placed inside the mother volume with respect to the coordinate system of the mother volume.

4.3 : VERIFICATION OF THE BETHE - BLOCH FORMULA

The Bethe - Bloch formula was verified using the help of the sample code named em0 from the “extended” list of the sample codes given. The stopping power of water as well as lead were calculated using this sample code. The electron and the proton were the two charged particles used in the simulation. The energy values were changed through the interactive open-GL window that is obtained when you run the code. The stopping power was plotted against the incident energy of the charged particles and a graph was plotted using root. The obtained plots were analyzed by comparing them with the standard plots obtained from plotting the standard values of stopping power of these materials obtained from PDG. We can see that they are almost identical.

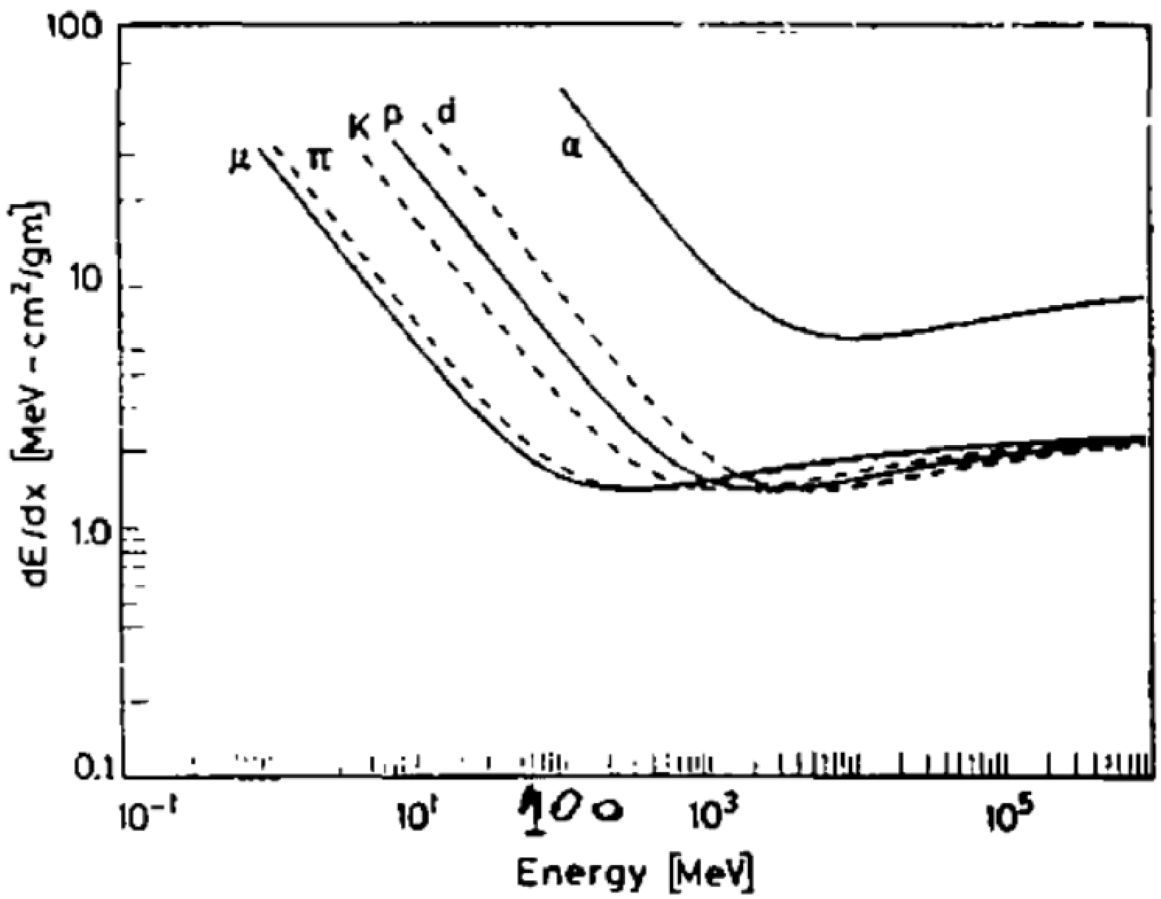
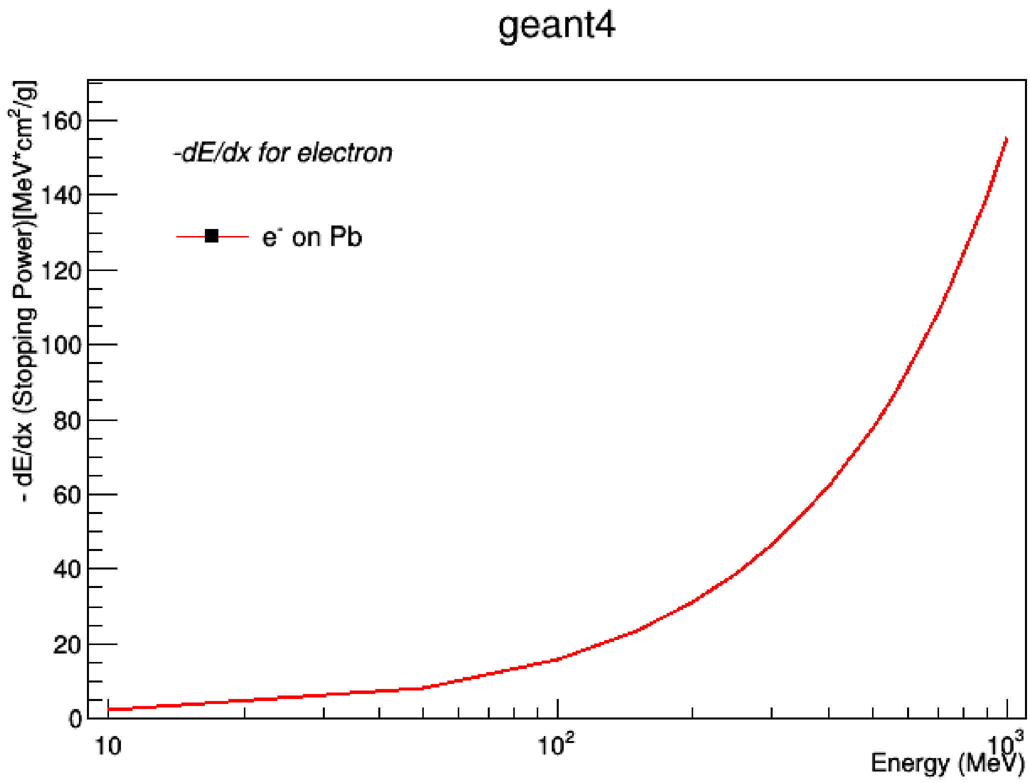
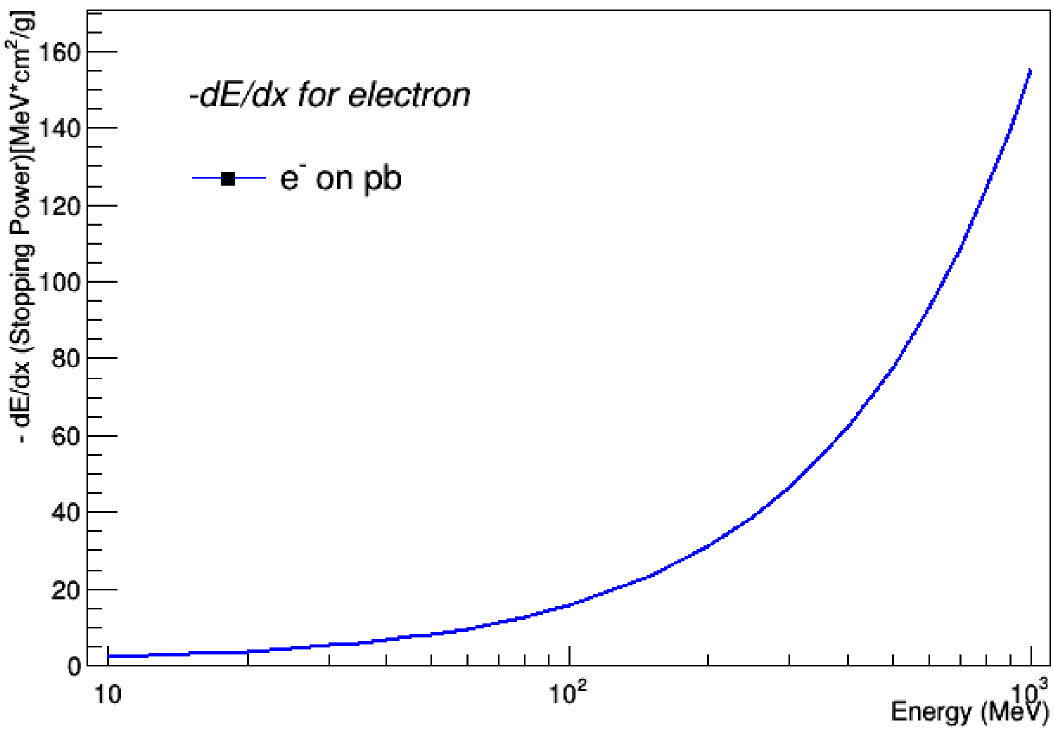


Figure 4.1 this figure shows the stopping power dE/dx as the function of energy for different particles. (taken from WR Leo – Techniques for nuclear and particle physics)

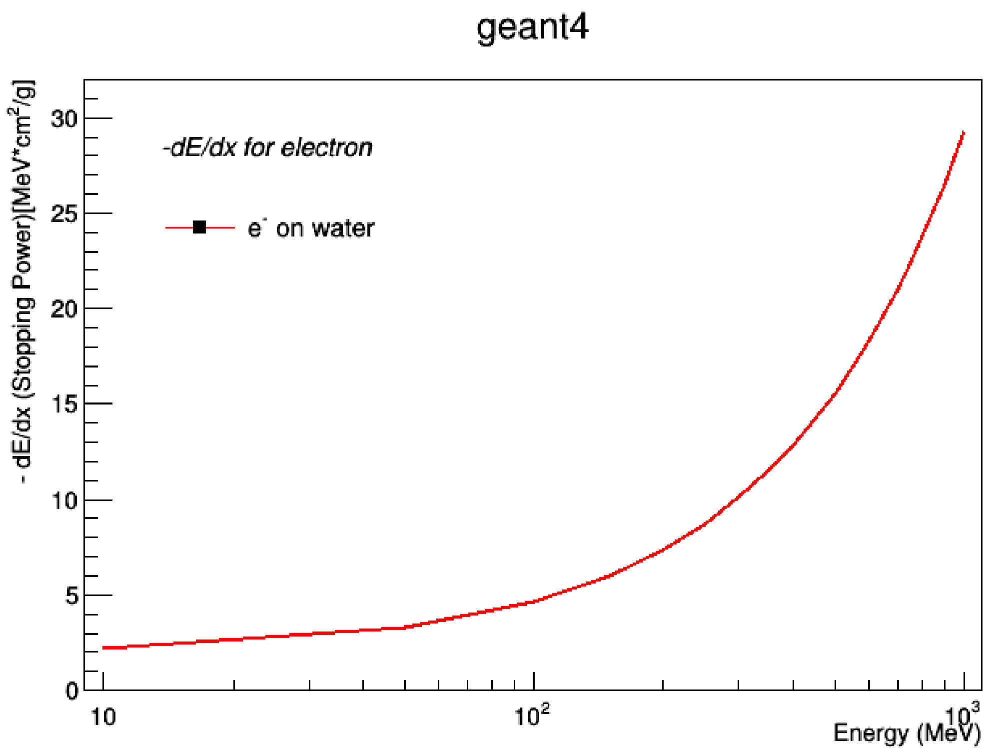
PLOT :1 - Electron incident on lead



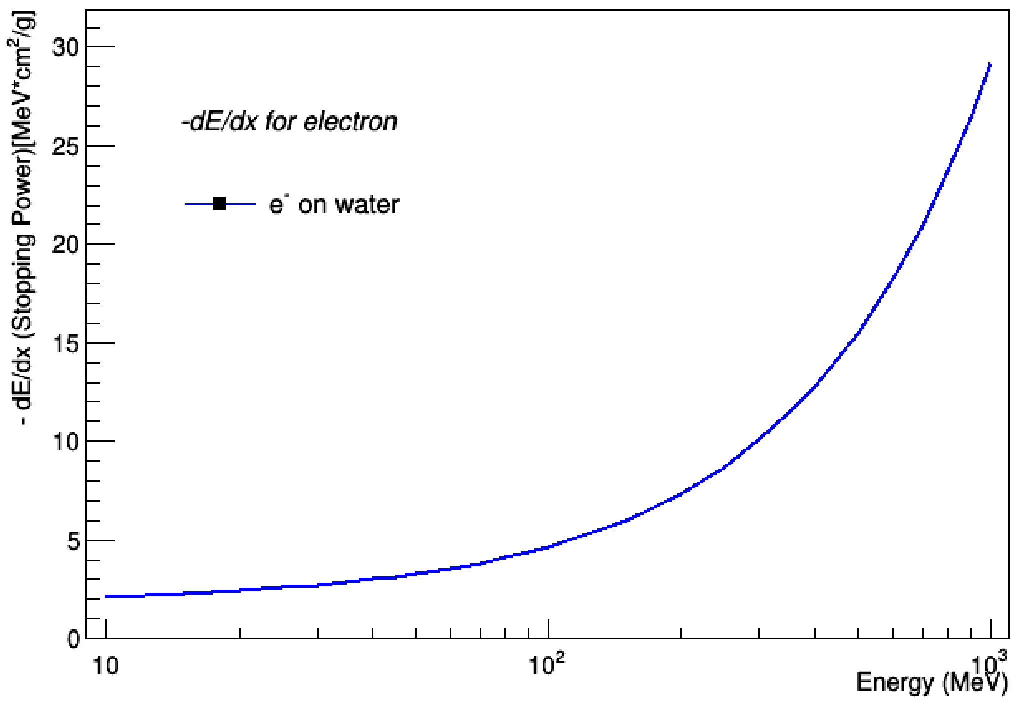
PLOT : 2 - Standard plot of electron incident on lead (PDG)



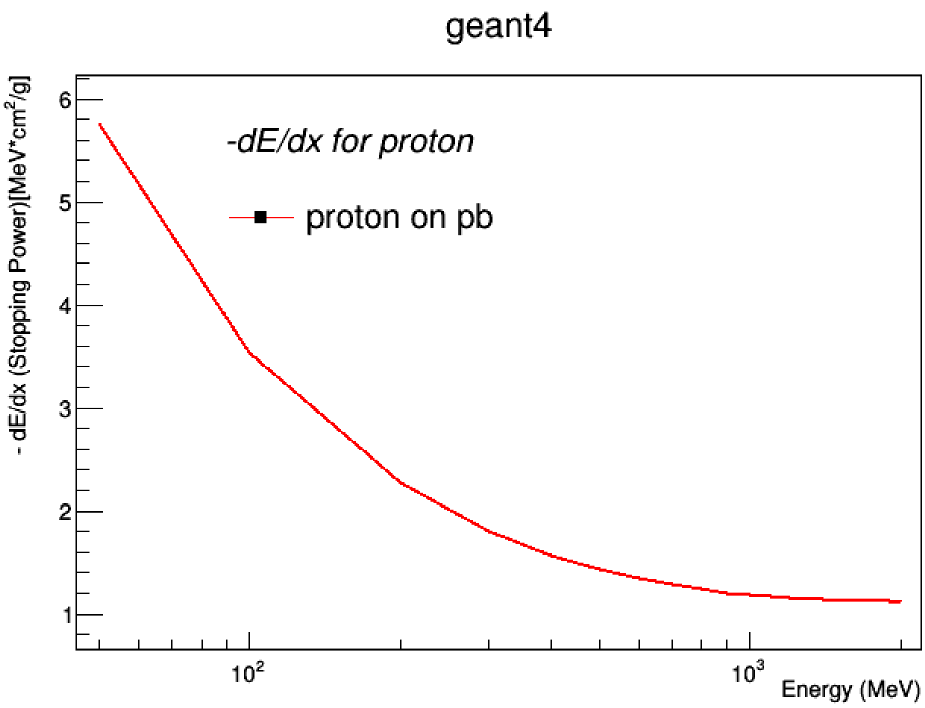
PLOT : 3 - Electron incident on water



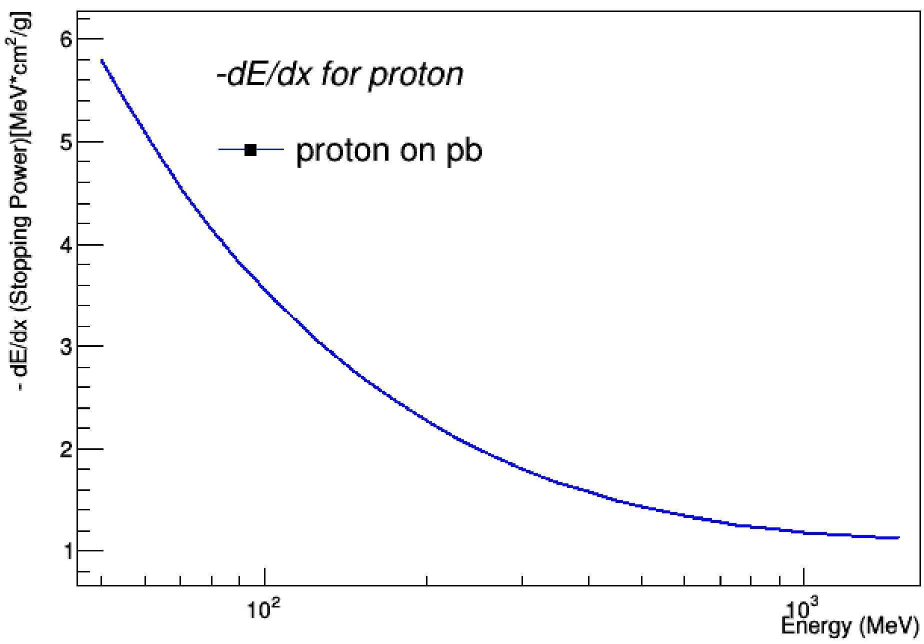
PLOT : 4 - Standard plot of electron incident on water (PDG)



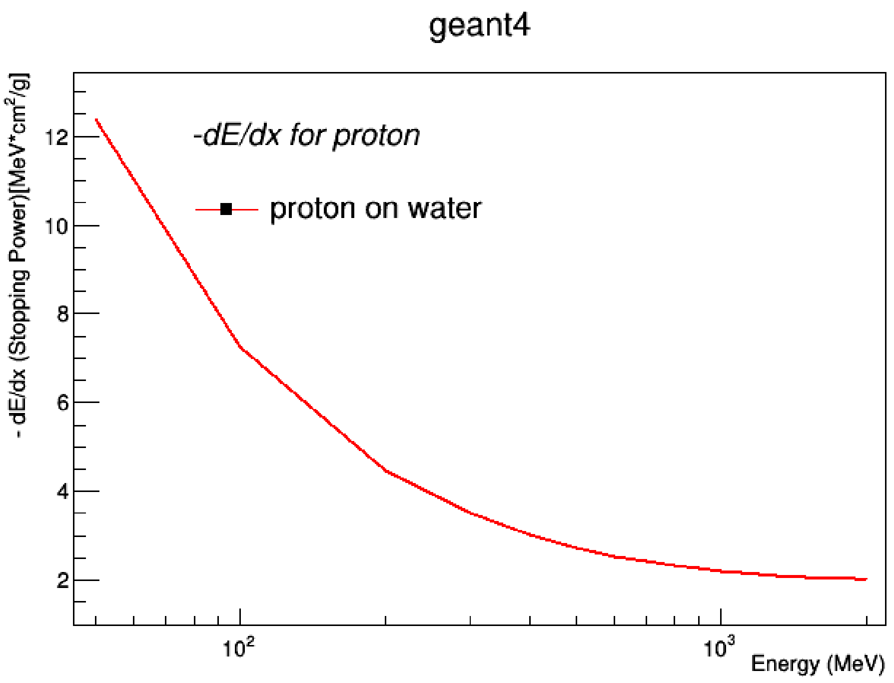
PLOT : 5 - Proton incident on lead



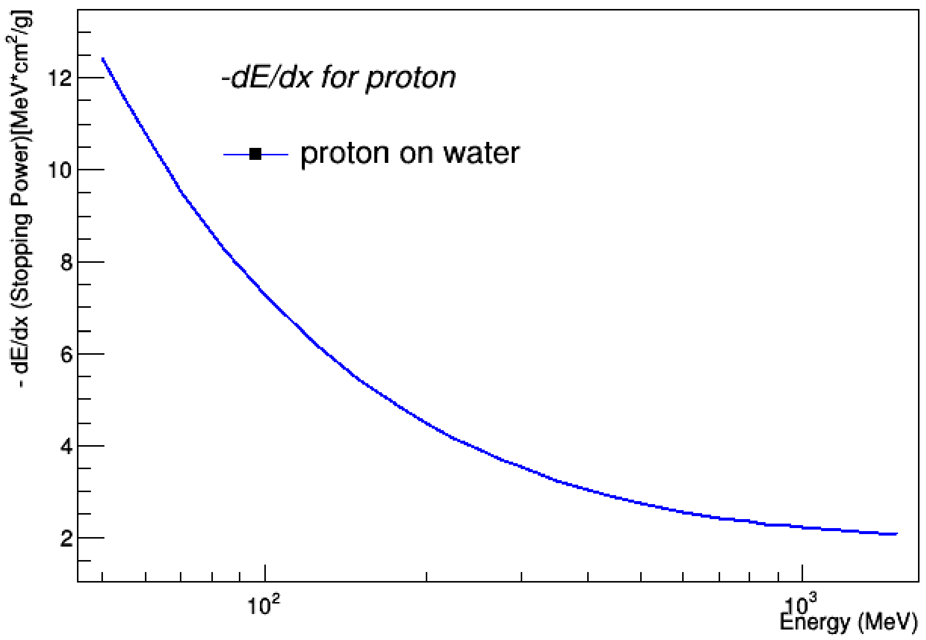
PLOT : 6 - Standard plot of proton incident on lead



PLOT : 7 - Proton incident on water



PLOT : 8 - Standard plot of proton incident on water



INFERENCE

The values of stopping power that were obtained using the Geant4 toolkit were very consistent with the standard values from PDG. This confirms that the values of stopping power obtained using Geant4 toolkit were very accurate. The results obtained showed the same characteristics as what was predicted by the Bethe - Bloch formula. The results for electrons were very much different from other charged particles. This is because in addition to losing energy from ionization like other particles, electrons experience another type of energy loss due to a process called Bremsstrahlung. This is also called breaking radiation energy loss. This effect is negligible in case of protons and alpha particles. This unique property makes the electron plots different from that of other heavier charged particles. Another huge difference between the plot of electrons and protons is that electrons at those kinetic energies are moving at relativistic velocities meanwhile protons are still moving at non relativistic velocities. This accounts for the opposite slopes of the two plots. This is because, as mentioned before at the upper limits of energy, the relativistic and the radiative effects come into picture. Another inference made was the difference in stopping power brought about because of the change in target material. The stopping power of lead was found to be much higher than that of water in the case of electron and the stopping power of water was found to be much higher than that of lead in the case of proton, in the energy ranges that were used for the study.

CONCLUSION

The stopping power of two different charged particles, the proton and the electron for two different media namely, lead and water was calculated. This was done through an object oriented toolkit named GEANT4 which is developed for the virtual study of high energy particles. The results of stopping power of electrons and protons in the two media obtained through GEANT4 were matching the results predicted by the Bethe – Bloch formula. The stopping power of materials in matter is obtained as it has useful applications for the study of biological effects, radiation damage dosage rates and energy dissipation at various depths of an absorber. It also has useful applications in the design of detection systems, radiation technology, semiconductor detectors, shielding and choosing the proper thickness of the target.

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