PHY411: Problem Set - 3 (8-10-2021)

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Problem 1

Since you have done the muon energy loss in previous assignment, this is an extend version of it. Let's say following particles are passing through a thin detector of thickness 10 cm (it is a 10 x 10 x 10 cm^3) detector.

Particle	Symbol	Rest Mass (MeV/c^2)	Mean Lifetime
Electron	e^-, e^+	$m_0^{e^\pm} = 0.511$	stable ($> 6.6 \times 10^{28}$ yr)
Muon	μ^-, μ^+	$m_0^{\mu^\pm} = 105.658$	2.197×10^{-6}s
Tauon	τ^-, τ^+	$m_0^{\tau^\pm} = 1776.86$	2.903×10^{-13} s
Pion	π^-, π^+	$m_0^{\pi^\pm} = 139.57$	2.6×10^{-8} s
Kaon	K^-, K^+	$m_0^{K^\pm} = 493.677$	1.238×10^{-8}s
Proton	$p, \bar{p}$	$m_0^{P,P} = 938.272$	stable ($> 2.1 \times 10^{29}$ yr)
Neutron	$n, \bar{n}$	$m_0^{n,n} = 939.565$	879.4 s (free)
Hydrogen	H	$m_0^{D} = 938.781$	-
Deterium	D	$m_0^{D} = 1875.6127$	-
Hellium	He	$m_0^{He} = 3727.379$	-

$1amu = 1.6605402 \times 10^{-24} gram = 931.39421 MeV/c^2$

The energies of each particles are uniformly distributed from 1 MeV to 10 GeV. Since the energy range is much bellow radiative loss regime, we can safely assume that the energy loss is only due to the ionization (you must neglect radiative effects for this problem).

1. There are 10,000 of each of these particles have passed through the detectors with uniformly distributed energies. i.e. $10 \times 10,000$ particles in total for above table.
2. You should use only Bethe-Block equation, don't use any aproximation.
3. Plot energy spectrum of each particles.
4. Calculate energy loss for each particles (you should use the energy loss due to ionization alone)
   (a) Plot momentum vs dE/dx plot for each particle
   (b) Plot momentum vs dE/dx plot for all particles in single plot.

Problem 2

A table of data is given for all elements in the periodic table (Files are uploaded in various format like txt, csv, json). You need to estimate what is the minimum energy required for a muon and an electron to penetrate through an unit *depth* of the hypothetical active volume made out of each element.

Element	Symbol	AtomicNumber	NumberofNeutrons	AtomicMass
Hydrogen	H	1	0	1.0070000000000000
Helium	He	2	2	4.002
Lithium	Li	3	4	6.941
Beryllium	Be	4	5	9.012
Boron	B	5	6	10.811
Carbon	C	6	6	12.011
Nitrogen	N	7	7	14.007
Oxygen	O	8	8	15.999

1. When muon and electron Energies are 20 GeV
   (a) Calculate and plot minimum energy loss vs atomic number
   (b) Calculate and plot the minimum energy loss vs atomic mass
   (c) Plot dE/dx vs atomic number plot for muon and electron
2. Plot minimum required energy vs atomic number. Hints: You need to use the approximation that we used in task-2