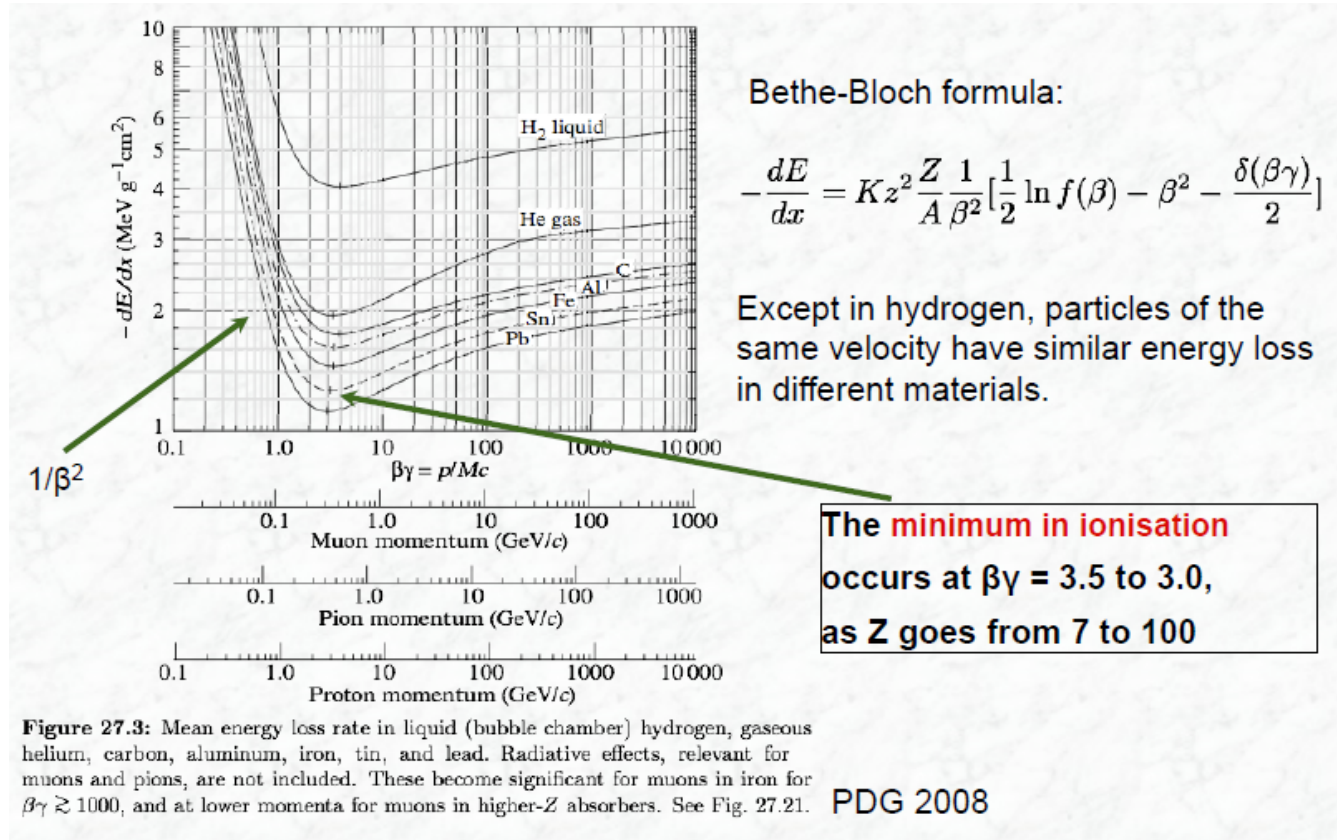# Energy loss of different particles

Different type of particles of the same kinetic energy and absolute charge behave differently in the same material. This is due to the Bethe-Block formula which is beta dependent.

Bethe-Bloch formula:

$$-\frac{dE}{dx} = Kz^2\frac{Z}{A}\frac{1}{\beta^2}[\frac{1}{2}\ln f(\beta) - \beta^2 - \frac{\delta(\beta\gamma)}{2}]$$

Except in hydrogen, particles of the same velocity have similar energy loss in different materials.

The **minimum in ionisation** occurs at βγ = 3.5 to 3.0, as Z goes from 7 to 100

Figure 27.3: Mean energy loss rate in liquid (bubble chamber) hydrogen, gaseous helium, carbon, aluminum, iron, tin, and lead. Radiative effects, relevant for muons and pions, are not included. These become significant for muons in iron for $\beta\gamma \gtrsim 1000$, and at lower momenta for muons in higher-Z absorbers. See Fig. 27.21. PDG 2008

This different energy loss can be used to identify particles.

Goal of these exercises

The aim of these exercises is to plot the energy loss of different particles in two different materials interleaved with a dense absorber.

beta versus rigidity distribution and determine Z/M in a given situation.

Basic informations:

you will work on a set of events coming out from a simulation. If working at INFIS please setup your environment using:

```
source /home/mocchiut/setup_infis.sh
```

you should develop the simulation from the example:

https://moodle2.units.it/pluginfile.php/146014/mod_folder/content/0/G4example-v2.tar.gz?forcedownload=1

which can be also found on INFIS here:

```
 /home/mocchiut/g4/G4example-v2.tar.gz
```

In these exercises, we will add to the simulation a scintillator paddle. Then we will simulate protons and muons with the same kinetic energy (80 MeV) and we will save energy deposit on the strip and on the scintillator in a ROOT file. Then we will use a script to plot the distributions of the observables. Finally we will fit the two distributions of energy deposit in the scintillator and we will get the ratio of energy deposit from the two different particles.

Exercise 1

Starting from the simulation code `G4example-v2.tar.gz`:

1. Add a scintillator paddle with the shape of a box (x,y,z) = (10,10,4) cm, centered in (x,y) = (0,0) and placed 2 cm behind the last volume present in the simulation (Y strip, NB: 2 cm gap, surface from surface). Hint: as material use NIST predefined scintillator material "G4_PLASTIC_SC_VINYLTOLUENE"

2. Save the energy release inside the scintillator in a new variable (e.g. eScint) inside the ROOTable class "DataClass".

3. Run the simulation over 10000 protons and 10000 negative muons at 80 MeV kinetic energy.

   NB: you can either run twice the simulation with two data cards and eventually sum the output root files with `bash>hadd all.root muons.root protons.root` or you can use just one data card and write twice inside the "/gun/particle" and "/run/beamOn" commands, once for muons and once for protons.

   NB2: if you are verbose in STDOUT (or use "verbose" in data cards) simulation will run tens of minutes on an INFIS PC, try first with 100+100 events or set "verbose 0" everywhere and do not printout from the code. If you have no time to run the full simulation, use the provided output file to do the next exercises (see next page).

Exercise 2

Write a ROOT-CINT <u>script</u> which reads the output file of exercise 1 (should be similar to this one: `/home/mocchiut/scripts/EM_output_260617.root` use this file if you are unable to complete or run exercise 1) and gives as output <u>on the screen and on the disk (pdf format)</u> a TCanvas containing :

1. the distribution of eScint versus eStrip1X (`TH2D`, X range - eStrip1X - [0.,1.5] Y range - eScint - [0.,80.], number of bins: 150 for both X and Y) with the condition that both eScint and eStrip1X are greater than zero.

You will notice that the two simulated particles distribute in two different locations in the histogram, permitting an almost 100% efficient identification. Can you guess which are the protons and which the muons? How could you change your script to draw only muons or only protons (hint: look at other variables in DataClass)?

Exercise 3

Update the script of exercise 2 in order to:

1. draw another TCanvas containing the Y projection of the TH2D histogram of exercise 2 (hint: look at method `TH2D::ProjectionY()`).

2. Fit the distribution around 10 MeV with a Landau function (hint: fit range [7,14]), fit the distribution around 70 MeV with a Gaussian function (hint: fit range [60.,80.]).

3. Draw the results of the fitting on the same projection histogram and in the whole range [0,80]; draw the Landau function as a green dashed line and the Gaussian function as a solid red line.

4. Print on the STDOUT the ratio between the Gaussian mean and the Landau MPV.

Save the canvas on the disk as pdf file.

Preparing the output

- create a directory and put inside this directory ALL the files you want me to correct and look at.
- create a README text file, inside the file write:
    – **your name and surname**
    – a list of the files you are submitting
    – **in details** how to compile and run the programs
    – any other comment and answer to question(s)

Timing and rules

- You have four hours time to do your work.
- You can search the web, look at manuals, look at any note you wrote during the course, etc.
- We will discuss what you have written at the oral examination on 2017/06/30, until that (if needed) you can change and improve your programs. In that case prepare an electronic version we can look at during the oral examination, we will compare it to the one handed in today and we will discuss any change and/or correction.