

# Stopping Power For Carbon, Oxygen And Proton Interacting With Adipose Tissue, Skeletal Muscle And Brain Using Different Formulas

Ahlam Habeeb Hussien<sup>#</sup>

<sup>3</sup>University of Kufa /College of Education for Girls

<sup>3</sup>Ahlahm.alkhursan@uokufa.edu.iq

**Abstract:** *In this research , the energy loss of electronic to projected carbon, oxygen and protons were calculated in targets (Adipose tissue, Skeletal muscle, and Brain)With using Bohr equation and Bethe equation with Bloch correction and Shell correction at the energy range of (20\_500) MeV . The calculations were compared with the experimental data of the SRIM 2012 .Since Bohr equation is classic, its results were a difference from the results of the practical program. As for Bethe's quantum equation, its results were Bloch correction that was closest to the practical program. As for the shell correction, it recorded a difference at specific energies and then began to approach with increasing range of used energy.*

**Keywords:** *Shell Correction, Bloch's Correction, Stopping power , Adipose tissue, Brain, Skeletal muscle.*

## INTRODUCTION

The study of the interaction of ionizing radiation (X-ray, electron, positron, proton, and heavy ions) with living tissue is of paramount importance in the treatment of cancer because the amount of energy transferred by ionizing radiation to cancer cells will determine the outcome of treatment. Radiation therapy for ions has become common because it can provide High-dose radiation to the target while avoiding adjacent healthy tissues and organs [1]

Proton energy can then be set so that the Bragg peak occur at the site of cancer. Thus the cancerous tissue receives doses much higher than the surrounding healthy tissue. The location where proton stopped is closely related to the amount of loss energy of medium, which is a measure of the amount of stopping power to the medium. The magnitude of the loss energy depends on the proton energy and the type of the target medium. To determine the distribution of the proton dose in the irradiated medium accurately, the stopping power of the protons must be calculated. [2]

Determination of proton energy corresponding to the location of the cancer become an important requirement in proton radiotherapy. The Bragg peak is very narrow so if shifted from the desired target will cause healthy tissue to exposed very high doses [3].

### CLASSICAL BOHR THEORY

The first theoretical model for the stopping power of a charged particle penetrating matter was Bohr classical stopping formula published in 1913. [4]

$$-\frac{dE}{dx_{ucn}} = \frac{4\pi z_2 e^4 z_1^2}{m_2 v^2} L_{nuc} \quad (1)$$

$$-\frac{dE}{dx_{elec}} = \frac{4\pi z_2 e^4 z_1^2}{m_e v^2} L_{elec} \quad (2)$$

With  $L_{nuc} = \ln\left(\frac{2a}{b_n}\right)$ ,  $b_n = \frac{2Z_1 Z_2 e^2}{m_0 v^2}$

$L_{elec} = \ln\left(\frac{m_e v^3}{2|Z_1|e^2 w^-}\right)$ ,  $w^- = (w_1 \cdot w_2 \cdot w_{Z_2})^{\frac{1}{2}}$

Where  $Z_1$  and  $Z_2$  the atomic number of projectile and target respectively,  $v$  the projectile velocity and  $L$  is stopping number,  $m_e$ ,  $e$  are the electron mass and charge,  $a$  is the target atomic radius,  $m_0$  is the reduced mass of projectile and target and  $w_i$  being a properly chosen binding frequency of the electron in the target atom.

### BETHE THEORY

Using quantum mechanics and relativistic physics, Bethe (1930) derived the equation of mass loss energy for a charged particle. In calculation, the energy transfer is determined in terms of the transfer momentum rather than the impact parameter, [5]

given by the Bethe expression:-

$$-\frac{dE}{dx} = \frac{4\pi z_1^2 e^4}{m_e v^2} Z_2 \ln \frac{2m_e v^2}{I} \quad (3)$$

There have been many corrections proposed to improve on Bethe theoretical approximations. this is done by expanding this equation in powers of  $Z_1$ , which can be used to add additional corrections to the ion and target interaction[6]

$$-\frac{dE}{dx_{elec}} = \frac{4\pi z_2 e^4 z_1^2}{m_2 v^2} [L_0 + Z_1 L_1 + Z_1^2 L_2 \dots] \quad (4)$$

$L_0$  Born Correction

Barkes Correction  $Z_1 L_1$

Bloch correction  $Z_1^2 L_2$

The loss energy term,  $L_0$ , contains the largest corrections to the basic high-energy loss energy function

is the main stopping number given by[7]

$$L_0 = \ln\left(\frac{2m_e c^2 \beta^2}{1 - \beta^2}\right) - \beta^2 - \frac{C}{Z_2} - \ln(I) - \frac{\delta}{2} \quad (5)$$

where  $\langle I \rangle$  ( $C/Z^2$ ),  $\frac{\delta}{2}$  represent, respectively, the mean excitation energy, the target shell corrections and the density effect correction which is neglected at low energies. Shell correction is the most important correction to Bethe formula especially below 1MeV proton energy. [8]. can write the shell correction in Bethe formula [9]

$$\frac{C}{z_2} = \ln \left( \frac{2m_e v^2}{I} \right) - L_0(v) \quad (6)$$

on can written the shell correction in Bethe formula[10]

$$\left( -\frac{C}{Z_2} \right)_{\text{Bethe}} = \epsilon \left[ 3 + \epsilon \left( \frac{5}{2} + \frac{7}{2} \epsilon \right) \right] \quad (7)$$

### BLOCH CORRECTION

Bloch showed that independent of the magnitude of the projectile charge a first-order perturbation treatment is sufficient for the distant collisions since terms odd in  $Z_1$  cancel and higher-order contributions of even terms. This leads to the so-called "Bloch correction", which is valid at non-relativistic and relativistic velocities. [11]

Bichsel has proposed a simple parameterization of the Bloch correction. which accurately fits a large range of high velocity stopping results [12].

$$Z_1^2 L_2 = -y^2 [1.202 - y^2 (1.042 - 0.855 y^2 + 0.343 y^4)] \quad (8)$$

where  $y = z_1 \alpha / \beta$  ( $\alpha=1/137$ )

### RESULT AND DISCUSSION

Figures (1, 2 and 3) carbon atom was projected in the targets of **Adipose tissue, Brain and skeletal muscles** in the human body at the energy range (20- 500) and equivalent electronic stopping power of classic Bohr equation and Bethe's quantum equation was calculated to correct Bloch and shell.

Figure (1) When the target was **Adipose tissue**, we notice that Bethe's equation with Bloch correction is the closest to SRIM practical results from the beginning of the range to its end, despite the slight difference recorded by the equation. As for Bethe's shell correction equation, it was far from the classical Bohr's equation at the beginning of the range, but at 40MeV energy By approaching the Bloch correction and the practical results by increasing the range of energy used, the Bohr equation remains recorded as a difference between it and the practical results along the energy range.

Figure (2) When the target was a **Skeletal muscle**, we notice that it behaves the same as Adipose tissue with a difference in the values of the stopping power, as the Beth equation with the two corrections records an approach to the practical results SRIM, especially at the range of (100)MeV. With the away of the Bohr's equation .

Figure (3) when the target was **Brain** The results are closer together from the beginning of the range to its end.

Figures (4, 5, 6) The oxygen atom was projected with the targets of **Adipose tissue ,Brain and Skeletal muscle** present in the human body at the energy range of MeV (20 – 500) and the electronic stopping power of the classic Bohr equation and the Bethe's quantum equation for the correction of Bloch and shell were calculated.

Figure (4) When the targets was **Adipose tissue**, then Bethe's equation to shell correcting is the farthest from the practical results, but it begins to approaching Bloch correction, and the practical results when increasing the range, especially at the range of 150 MeV to the end of the range, are almost applicable, as for Bohr's equation, it remains recorded as a difference from the beginning of the range to its end.

Figure (5) When the target was a **Skeletal muscle**, we note that it behaves the same behavior in Figure (4) with a difference in the stopping power values as it records a greater difference at the beginning of the range and up to 150MeV.

Figure (6) We notice that it behaves the same behavior with its approaching of the values of stopping power since the beginning of the range, and that the shell correction begins to be very approached the Bloch correction and the practical results at the energy range of 70MeV. As for the Bor equation, it remains recorded as a difference from the beginning of the range to its end.

Figures (7 , 8, 9) Protons was projected in targets **Adipose tissue,Brain and Skeletal muscle** present in the human body at the energy range of MeV (20-500) and the electronic stopping power was calculated the classic for Bor's equation and the Bethe's equation to Bloch correction and shell correction.

Figures (7, 9), when the target was **Adipose tissue and Brain**, we note the strong applicability for the Bethe equation with corrections of Bloch and Shell with the practical results from the beginning of the used range to its end. As for the Bor's equation, it makes a big difference over the used range.

Figure (8) When the target was a **Skeletal muscle**, we note the applicability of shell correction with Bloch correction over the entire range used with very little difference with the practical results.

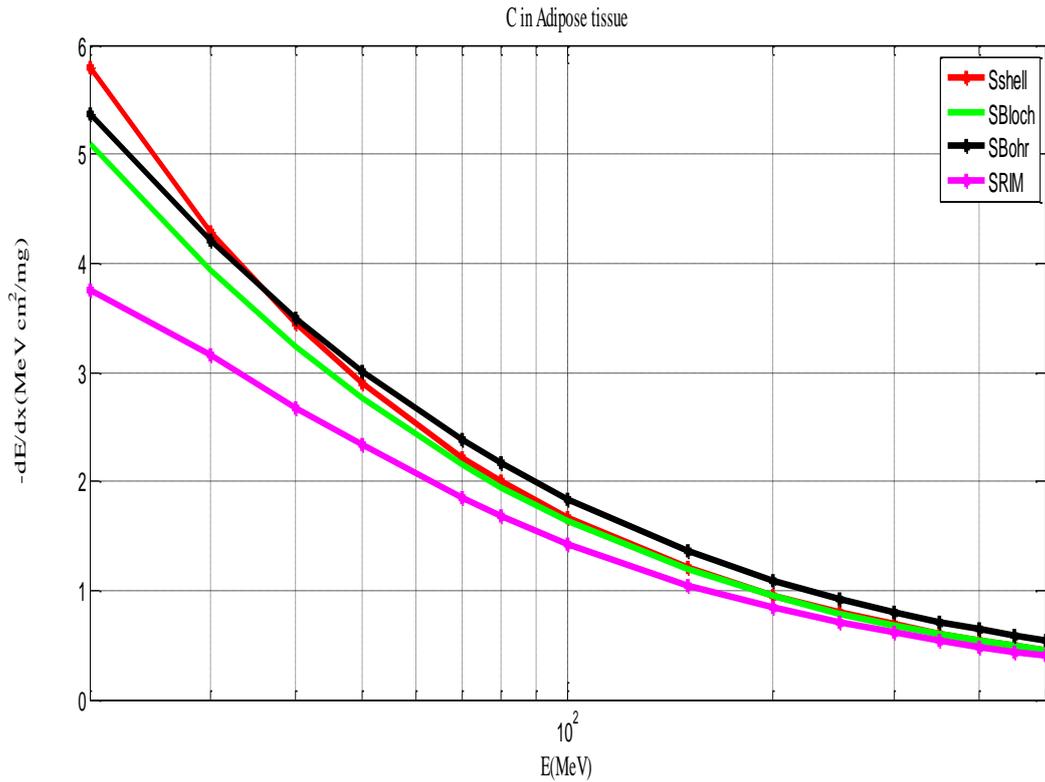


Fig.(1) stopping power for Carbon in (Adipose tissue)

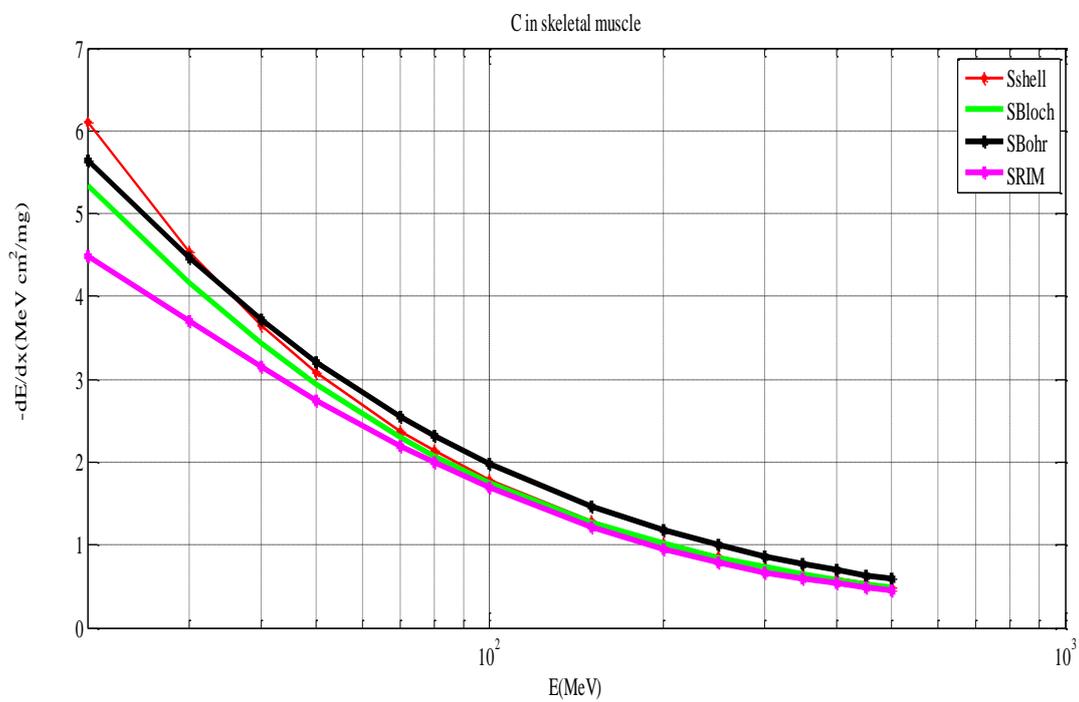


Fig.(2) stopping power for Carbon in (Skeletal muscle)

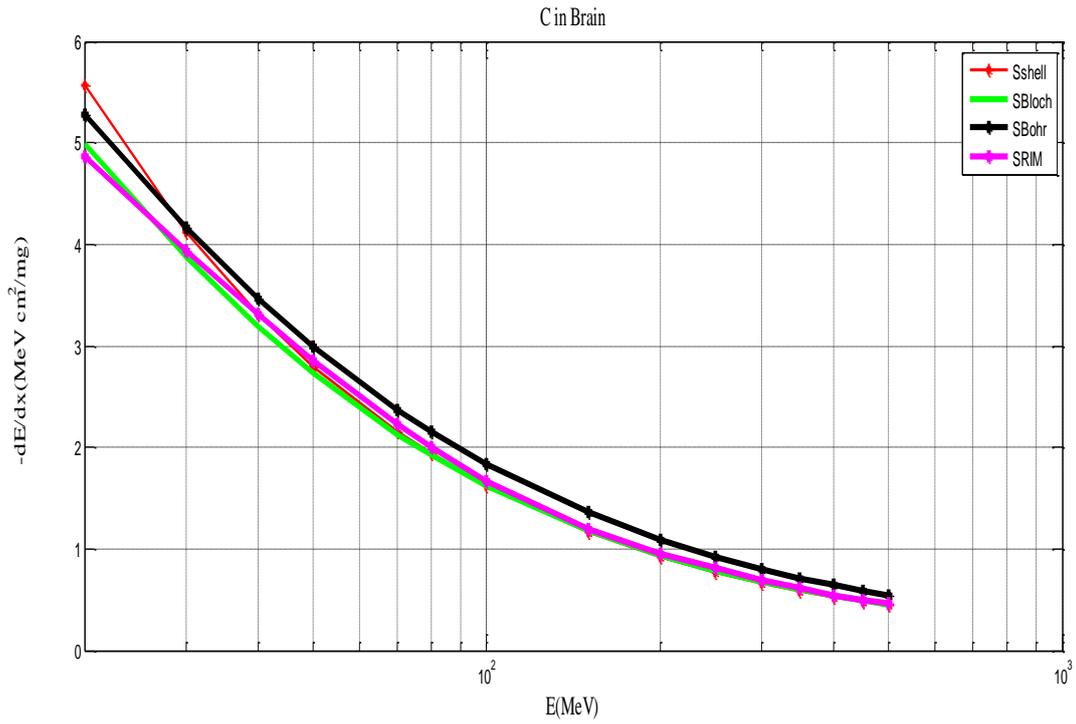


Fig.(3) stopping power for Carbon in (Brain)

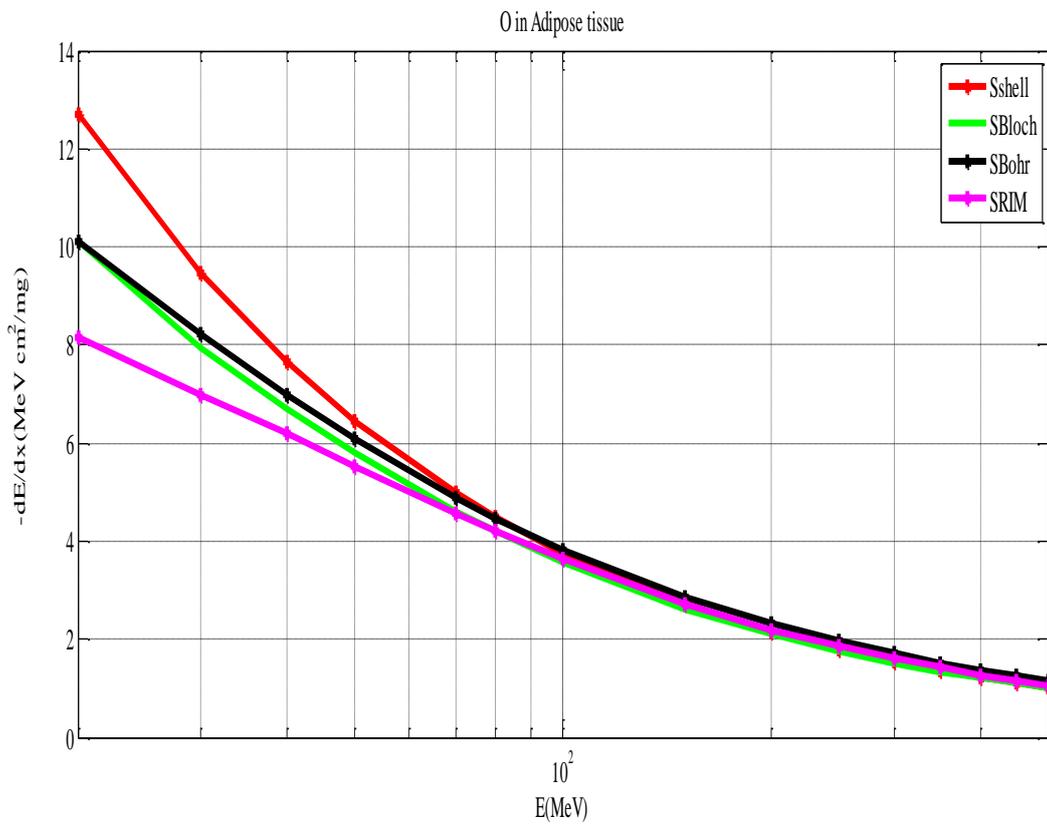


Fig.(4) stopping power for Oxygen in (Adipose tissue)

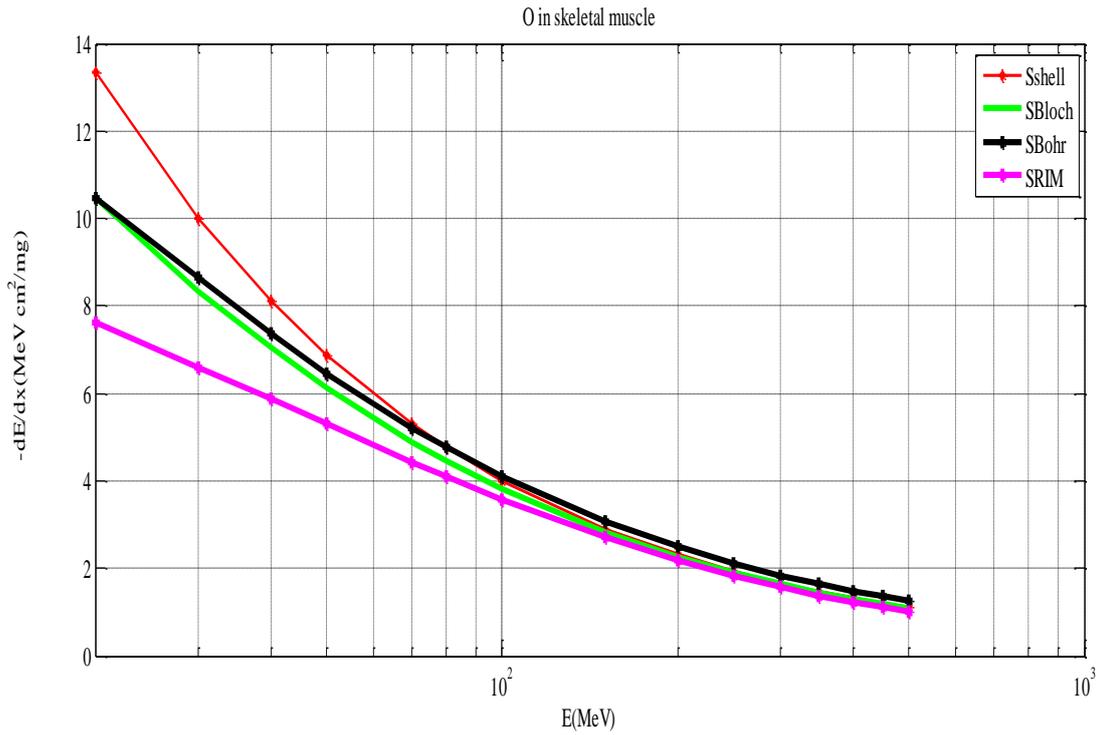


Fig.(5) stopping power for Oxygen in (Skeletal muscle)

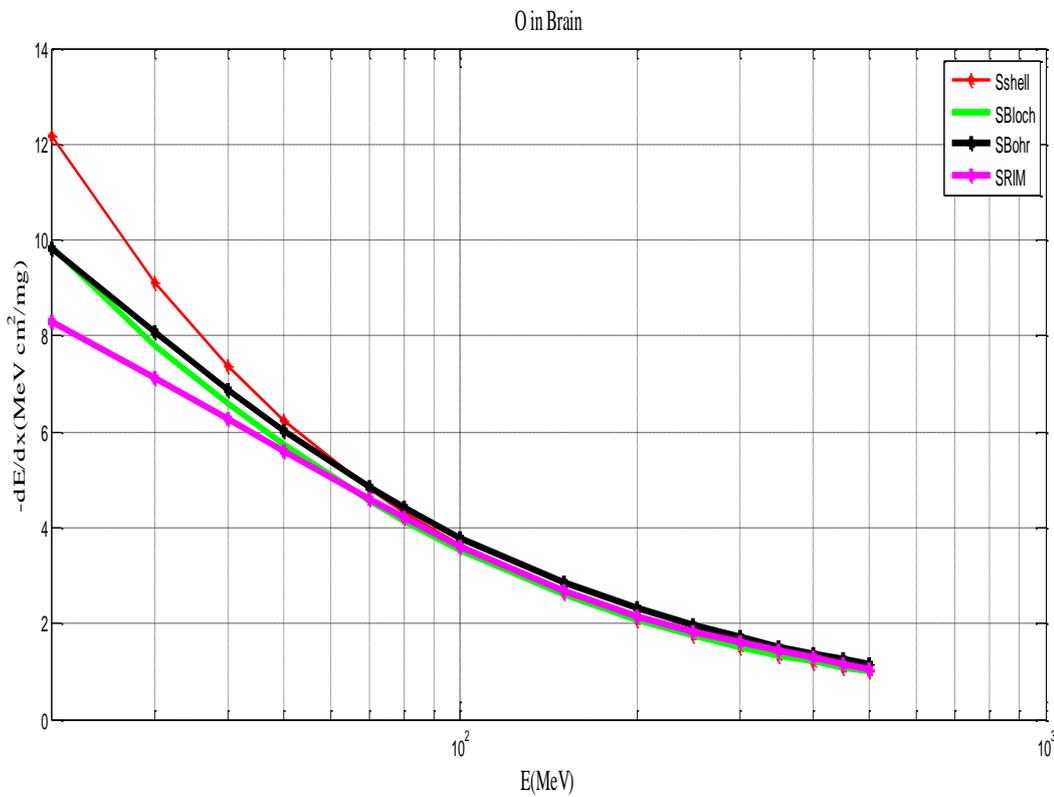


Fig.(6) stopping power for Oxygen in (Brain)

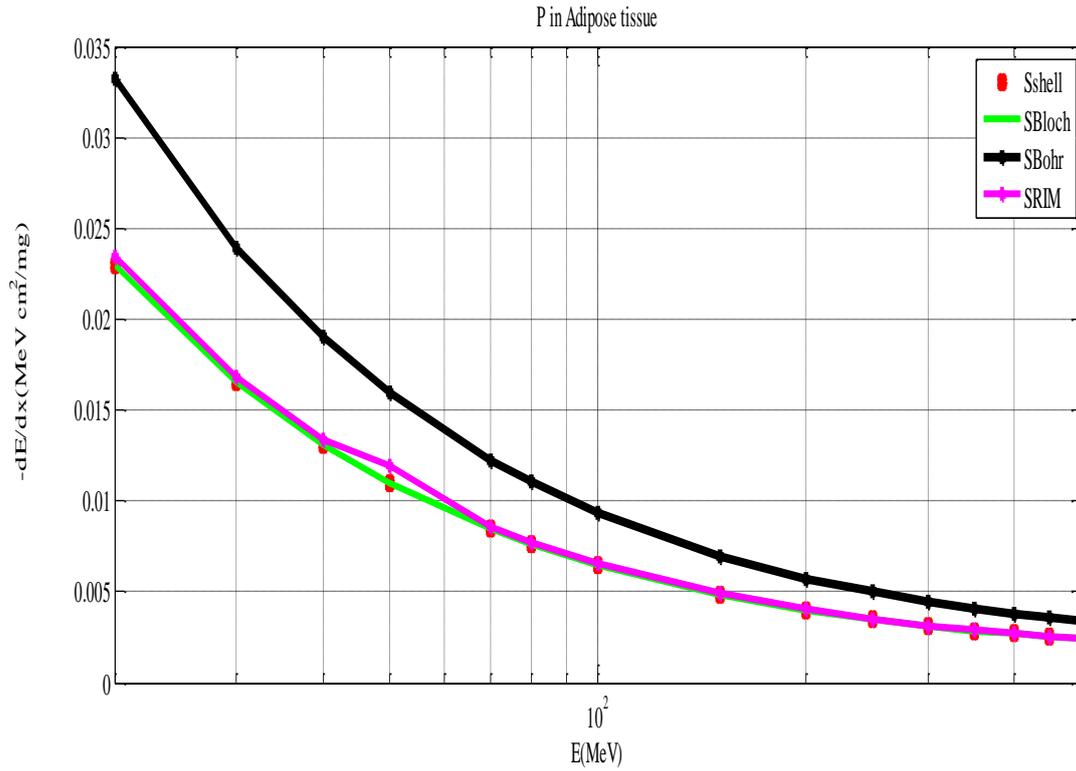


Fig.(7) stopping power for Proton in (Adipose tissue)

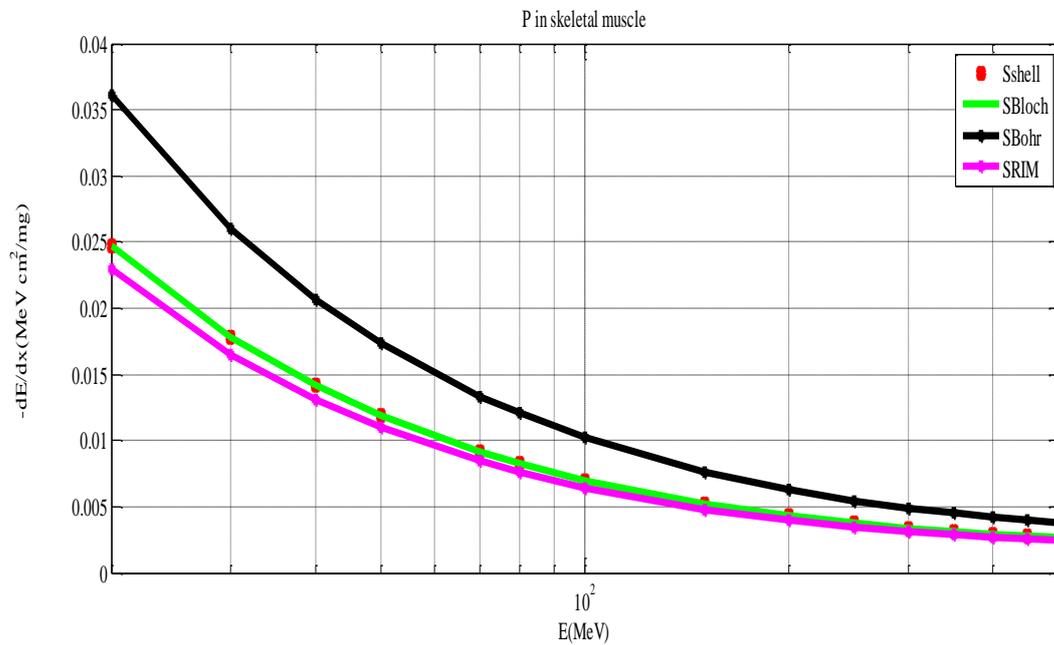


Fig.(8) stopping power for Proton in (Skeletal muscle)

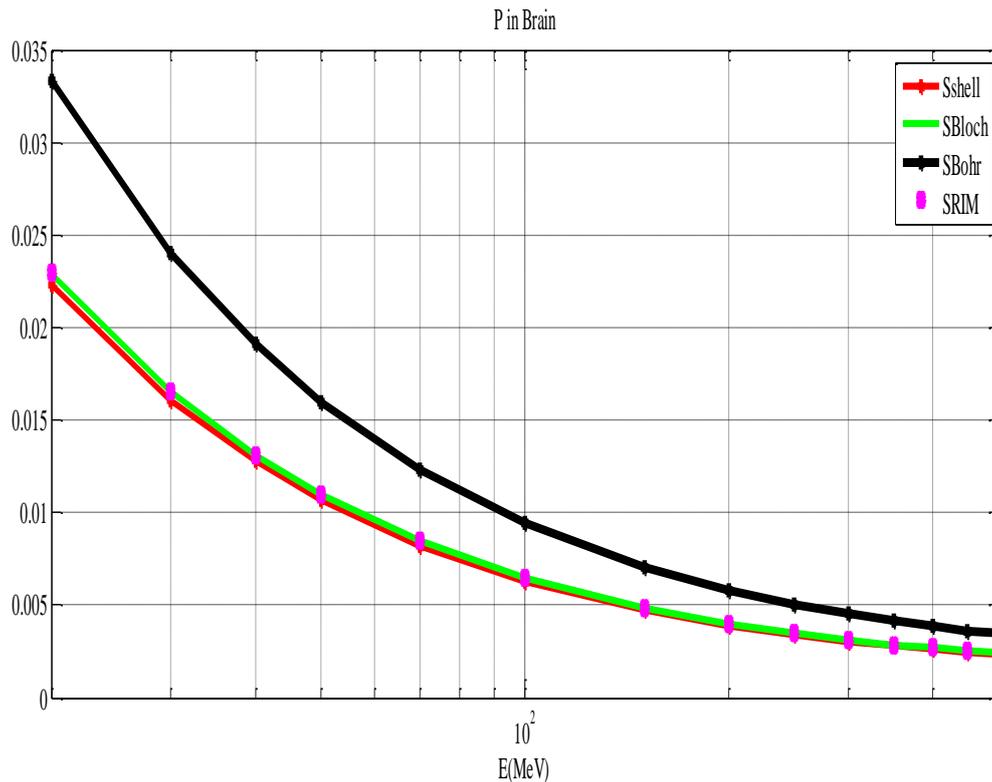


Fig.(9) stopping power for Proton in (Brain)

## CONCLUSION

- 1- Beth's equation with Bloch correction is the best result in comparison with Bohr's equation and Beth's equation with shell correction
- 2- When the projected is a proton, it gives good results with the practical SRIM program.
- 3- Shell Correcting records good results at energies higher than (70)MeV.
- 4- The classic Bohr's equation is not suitable for calculating the stopping power at the range used in the research.

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