



ACHIEVING A THEORETICAL APPROXIMATION CHARACTERIZE THE STOPPING POWER OF HEAVY ION IN D-T PLASMA

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ABSTRACT

The dependence of the energy losses or the stopping power for the ion contribution in D- T hot plasma fuels upon the corresponding energies and the related penetrating factor are arrived by using by a theoretical approximation models. In this work we reach a compatible agreement between our results and the corresponding experimental results.

Keyword: D-T plasma, stopping power, heavy ions, energy loss, particle range, inertial confinement.

1. INTRODUCTION

The issue of interaction of charged particles beams with substance has been attracting more and more interest in active scientific researches for whole decades because of the evolution charged Particles accelerations and detectors. active participating does not include only essential physics but also include thermonuclear physics ,medicinal radiology and substances sciences [1] when the charged particles interact with matter they loss their energy by various styles from no charged radiation (such as neutrons, gamma or x rays). a single incident photon or neutron on substance possible pass into the substance without loss energy or loss its energy by some ways the energy losses by considerations because of existence of coulomb electric strength field around charged particle that interacts with one or most electrons or also with the nucleus. Only few amount of kinetic energy for incident particle can be transmitted during these interactions. The kinetic en-energy of particles miss out in friction such as this process progressively. Most point to as the slowing down approaches uninterrupted [2]. Pass of charged particles in to substance generally has two major advantages are miss out energy and deflection of particles from original incident trajectory these are because of two processes

- a) Particles collide with atomic electrons of substance (elastic collisions)
- b) Scattering of particles from nuclei (elastic and inelastic scattering)

The unique official approximately for losses in energies of charged particles in matter is the first process energy loss in these collisions lead to the ionization or excitation of atom. in the general an extremely small portion from total kinetic energy of particle is transmitted in every collision. Although huge number of collision per unit trajectory length. the atomic collision are classified to two various categories the first category just an ex-excitation is achieved that called soft collision and the second category that causes ionization if energy transmitted is enough to that called hard collisions [3] in

the several of hard collisions the energy transmitted is enough in which large secondary ionization is obtained .as long as masses of nuclei of most materials are normally large in comparison with incident particle. The energy transmitted in elastic scattering is extremely small the inelastic collisions are achieved with particular quantum mechanical possibility and they from statistical nature .although they have large number per macroscopic trajectory length the collisions in the total losses of energy are small we can take average losses energy per unit trajectory length named stopping power [4]. one of the most important ways to get everlasting energy is nuclear fusion that characterized by a clean resource such as deuterium which is available in the water but there are numerous difficulties in requirement of this energy source that represented by high density and temperatures both necessary for deuterium nuclei to be fused the substance which have these conditions named as plasma it contains of photon, neutral atoms positive ions and electrons [5] the energetic beams are used to produce plasma such as ion beams or leaser [6] in both beams responsible about deposited energy on target is electronic stopping is can be used to find magnitude of density and temperature plasma [7] this stopping include free and bound electrons contributions[8]. There is main variations in energy transferred between ion beams and leaser breakthrough and loss of their energy well into target and they stopped at limited range their maximum released energy at the end of range that called Bragg peak this is do not like laser - driven fusion in which no critical density plasma [9].

In the reaction ${}^2_1\text{H} + {}^3_1\text{H} \rightarrow {}^4_2\text{He} + {}^1_0\text{n}$

The alpha particles are emitted firstly that occur in a magnetic fusion reactors alpha particle birth with (3.5 MeV), also liberate the neutron with (14.1 MeV) that is in like this reactor going away the plasma to produce tritium and make to generate steam by heat blanket during collision the alpha particles are going to be locked up into magnetic field that lead to heat layers of plasma that occur when heating average of alpha particle is similar (or largest) than wasted energy average in plasma therefore the plasma ought to ignite and the burning procedure going to be self-sustained in plasma[10].



Many of the countries around the world interested in (ICF) the powerful lasers are used to make nuclear fusion is achieved to get clean energy source [11] the target is represented by spherical plastic cap with stratum from (DT) ice and contains of (DT) gas [12] where laser beams blows ablate which covers the target and internal explode the target by effect of projectile[13] compress the(DT) making highest pressures and temperatures when the powerful laser - driven traumas the spherical target that is very important to fuse (DT)together to liberate neutrons and energetic alpha particles with (3.5 MeV) according reaction above. Because of the explosion the plasma suffer differences in temperature and density where in shell the temperature is slow and density is high whereas in hot spot the temperature is high and medium density in the target enter where the alpha particles are produced there which is carries the important energy to additional heat(DT) plasmas for occur further fusion reaction this process called ((bootstrapping)) that is in the ending leads to ignition and gained energy. ignition is when both output and input energies are equal or gain=1,the gain is the ratio output energy to input energy. charged particles deposit of their energies when they pass in plasma .Due to neutrons do not have charge magnitude by plasma it does not important and their influence by plasma is misfit amount of energy that is returned to plasma from alpha particle.(stopping power) is contributed in determining the ((boot-strapping)) effectiveness [12]

2. THEORY

2.1 Ion-ions scattering in plasma

Its necessary to pointed that Chandrasekhar is first theory that is used to calculate advantages non equilibrium [14]for gravitational forces and SPIZER copied to the situation for electrostatic forces [15].in plasma the influences of collisions have to studied in order to development of theory The relaxation process can be studied by this theory such as when both ions and electrons have various temperatures stationary state process as the transmit of electric current or heat. the long range is advantaged for electrostatic forces however, it have to consider much the effect of away collisions and not very much the effect for near collisions in which the angle of scattering is teeny if \bar{T} indicated impact parameter and θ is the defection angle, μ is the relative velocity

$$\tan \theta = w_{12} \bar{T} \mu^2 / q_1 q_2 e^2 \quad (1)$$

Where w_{12} is indicated the reduced mass and $q_1 q_2$ are charges on particles $w_{12} = w_1 w_2 / w_1 + w_2$ (2)

In the near collision the defection is lower than ($\pi/2$) the impact parameter become

$$\bar{T} = q_1 q_2 e^2 / w_1 \bar{v}_1^2 \quad (3)$$

Where \bar{v}_1 is the corresponding relative velocity?

$w_1 \ll w_2$ And cross -section is $\pi \bar{T}^2$ for example this collision the time of collision is

$$t_c = 1 / \pi \bar{\rho} \bar{v}_1 \bar{T}^2 \quad (4)$$

where ρ is particles density in the plasma the very long mean free trajectory before charged particles in gas that because of the electrostatic forces in the truth weakly reduced with distance that due to large effect of very far collision the do not reopens for increasing cross-section they must be analyzed since the deflections are based on random nature statistical analyzing someone defines statistical averages of components of different velocity(for example through Maxwell-Boltzmann distribution) that mean

$\langle (\Delta \vec{v}_{\parallel}) \rangle$, $\langle (\Delta \vec{v}_{\perp})^2 \rangle$ and $\langle (\Delta v_{\parallel})^2 \rangle$ when \parallel indicate parallel to exam particles beams which traversing into the group of charged particles others that include specific velocity distribution after that it can be explained [15] for example

$$\langle (\Delta \vec{v}_{\parallel}) \rangle = - C_0 s_f^2 \left(1 + \frac{w_1}{w_2} \right) k (s_f \vec{v}) \quad (5)$$

$$C_0 = 8 \pi e^4 \bar{\rho} q_1^2 q_2^2 \ln \Lambda / w_1^2 \quad (6)$$

$$\text{Where } \bar{\phi}(x) = 2 / \pi^{1/2} \int_0^x e^{-y^2} dy \quad (7)$$

$$k(x) = (\bar{\phi}(x) - x \bar{\phi}(x)/x^2) \quad (8)$$

$$s_f = \sqrt{\frac{w_2}{2kT_f}} \quad (9)$$

Where T_f temperature, $\ln \Lambda$ is coulomb logarithm and q_f is charge

$$\Lambda = 3 / 2 q_1 q_2 e^2 (K_B^3 T_f^3 / \pi \rho_e)^{1/2} \quad (10)$$

Where ρ_e is electron density $\langle (\Delta \vec{v}_{\parallel}) \rangle$ is related to the energy loss average and from this we can derive formula for energy loss for ion passes through plasma with losses of energy because of both ions and electrons in ion - ion scattering for cold matter which it given in section (2.2) these kinds of formula are not convenient but they are appropriate for plasma is full ionized.

2.2 Generalion - ion scattering

The plasma shaped on external layers of inertial confinement fusion pellets and essentially mental plasma that is produced when the powerful ion beam make to the plane target is irradiated [16] in this kinds of plasmas the ion - ion scattering is not very significant because of initial ion velocity(projectile ion)is extremely large and also normally much greater than the velocity of electron the stopping power is often almost constant or crease to a simple peak when the velocity of ion within of velocity of electron the $d(\frac{dsp}{dx})$ reduces very sharply and the projectile ion losses all its energy virtually as long as velocity of ion



is less than the velocity of thermal electron. Very various states is occurred when alpha particles or neutron induced blow on tritium and deuterium ions traversing through burning (D-T) which is very hot such as the alpha particle starts with velocity larger than thermal velocity of ion and less than thermal velocity of electron when the ion projectile velocity have the same thermal velocity average for both electrons and ions. In hot plasma the loss of energy to electron and ion is forever largest [17]. On the other hand the stopping power is reduced for this velocity value. When an alpha particle slows down with (3.5 MeV) the loss of energy due to ions increases and due to electrons decreases the loss due to ions be very more important comparative to loss to electrons when the temperature of plasma increases in inertial fusion plasma as long as the property time of electron - ion relaxation is longer than burning time. Temperature of ion and electron for each other can be various so sequentially at the ion and electron temperatures the loss of energy for them must to be calculated. these contribution plus contribution of nuclear scattering the total loss can be calculated by way suggest the code obeys to Mehlhorn [18,19] the ion-ion scattering can be treated on other side approach of dielectric function theory use in code for stopping power of electron that is characterized much precise than Mehlhorn which is use simple binary collision model inside radius of Debye addition to that interactions out the Debye sphere with waves of plasma, The stopping power of ion in this method is obtained by:

$$\frac{ds}{dx_i} = q_{eff}^2 q_2 e^2 / \gamma^2 c^2 B_2 \left(\frac{m}{m_p} \right) \omega_{pl}^2 R(U_i) \ln \Lambda_i \quad (11)$$

$$\text{Where } U_i = (B_2/B_1) (s/K_B T_i) \quad (12)$$

$$R(U_i) = \text{Error function} (\sqrt{U_i}) - 2 \sqrt{\frac{U_i}{\pi}} (\exp(-U_i)) \quad (13)$$

$$\omega_{pl}^2 = 4\pi n \bar{q}_2 e^2 N_A / m_e B_2 \quad (14)$$

where S_i is the ion energy, e is charge of electron, n is the density, \bar{q}_2 is ionized electrons number average per atom, N_A is number of Avogadro, B_1 is the atomic weight of ion, B_2 is the atomic weight for plasma ion, T_i is ion temperature, q_{eff} is the effective charge

$\gamma = v/c$ is light velocity, v is velocity of ion, m is the mass of electron, m_p is mass of proton, ω_p is the frequency of plasma, $\ln \Lambda_i$ is the coulomb logarithm for ion

$$\Lambda_i = A_{MAX}/A_{MIN}$$

Where

$$A_{MAX} = \text{Debye Radius} = (K_B T_e / 4\pi \rho e^2)^{1/2} \quad (15)$$

$$A_{MAX} = (\mu \gamma^2 / q_1 q_2) (m_p c^2 / e^2), \quad \mu = (B_1 B_2 / B_1 + B_2) \quad (16)$$

where T_e is temperature of electron and ρ is density of electron Mehlhorn used for loss of plasma electron symmetric expression [18,19]

$$\frac{dsp}{dx_{free}} = (\omega_{pl}^2 q_{eff}^2 e^2 / c^2 \gamma^2) k (U_e) \ln \Lambda_{free} \quad (17)$$

$$U_e = m c^2 \gamma^2 / 2 K_B T_e \quad (18)$$

$$\Lambda_{free} = 0.764 \gamma c / A_{min} \omega_{pl} \quad (19)$$

$$A_{min} = \max(e^2 q_1 / w_{12} \bar{\mu}^2; \hbar / 2 w_{12} \bar{\mu}) \quad (20)$$

Where $w_{12} = w_1 w_2 / w_1 + w_2$, w_1 is arriving ion, w_2 is plasma ion mass and $\bar{\mu}$ is the relative speed between the projectile of ion and the electrons of plasma, the formula above gives magnitude greater than dielectric function theory for dsp/dx [16].

2.3 Stopping power of alpha particles

by pursuing Ray and Hora [20, 21] and calculate alpha particle range $R = \rho h$ by using coefficients of Fokker - Planck correctly [22, 23, 24] take into account distribution for various types of particles indicated by z, v, \dots if $F_z(\vec{r}, \vec{s}, t)$ represented as distribution function for kinds z its evolution is restricted from Fokker - Planck equation

$$\partial F_z / \partial t + s_i \partial F_z / \partial h_i + f_i / m_z \partial F_z / \partial s_i = \sum_t \sum_{n=1}^{\infty} (-1)^n / n! d^{(n)}(\gamma_{(n)}^{tz} F_z) \dots \quad (21)$$

over all kinds their sum expands, f_i is the i th exterior force component ($i = 1, 2, 3, 4$), \vec{r} vector of space coordinate \vec{s} is vector for velocity m_z is kinds mass z and t the time

$$\text{Where, } (\partial)^n = \partial^n / \partial s_{i1} \partial s_{i2} \dots \partial s_{in} \quad (22)$$

$$\gamma_{(n)}^{tz} = \gamma^{tz} (s_{i1}, s_{i2} \dots s_{in}) \quad (23)$$

Where Fokker - Planck coefficients are represented by γ the formalism for Fokker - Planck take in to account for two opinions the first one as random description for average of variation of the possibility distribution function in gathering of particles in this case to describe the variation of thermodynamic equilibrium velocity (that symmetric to Markov process) [22, 23] take averaging the secondly as an approximate expressing for collision non fragmented in equation of Boltzmann the equilibrium of thermodynamic is not suggested in eq(2.21). We take two kinds of particles for plainness the are an alpha particles and electrons we ignore the interaction for alpha particles and also ignore their interaction with ions for the time being

Let be velocity function \vec{s} only $\Psi(\vec{s})$, average $\bar{\Psi}$ that related to the distribution function F is given by

$$\bar{\Psi} = \int \Psi F d^3 \vec{s} / \int F d^3 \vec{s} = 1/n \int \Psi F d^3 \vec{s} \quad (24)$$



Where $d^3\vec{s} = ds_1 ds_2 ds_3$, $n = n(\vec{r}, t) = \int F d^3\vec{s}$ represent local density by integral eq (2.11) to $d^3\vec{s}$ and multiplying by $\Psi(\vec{s})$ we get

$$\frac{\partial}{\partial t}(n_\alpha \bar{\Psi}^\alpha + \frac{\partial}{\partial x_i}(n_\alpha \bar{\Psi} s_i^{(\alpha)}) = 1/m_\alpha M_\alpha \partial \left(\frac{\bar{\Psi} f_i^{(\alpha)}}{\partial s_i} \right) + \sum_{n=1}^{\infty} (-1)^n / M_i \int \Psi d^{(n)}(\gamma_{(n)}^\alpha F_\alpha) d^3\vec{s} \quad (25)$$

Where α alpha particles and e is electrons by using $\Psi(\vec{s}) = 1/2|\vec{s}|^2$ and evaluating this equation and averaging into consideration for alpha particle one obtains

$$\left(\frac{1}{2} \right) \frac{\partial}{\partial t}(n_\alpha \bar{s}^{2(\alpha)}) + \frac{1}{2} \frac{\partial}{\partial x_i}(n_\alpha \bar{s}^2 s_i^{(\alpha)}) = n_\alpha (a_i s_i^{(\alpha)} + \frac{1}{2} b_{ij} s_{ij}^{(\alpha)}) \quad (26)$$

Where $a = \gamma(s_i)$ and $b_{ij} = \gamma(s_i, s_j)$ are represent Fokker - Planck coefficients. To obtain particular alpha particle with velocity and location $(\vec{r}_\alpha, \vec{s}_\alpha)$, we put

$$F_\alpha = \sigma[\vec{r} - \vec{r}_\alpha(t)] \sigma[(\vec{s} - \vec{s}_\alpha(t))] \quad (27)$$

Giving $n_\alpha = \sigma(\vec{r} - \vec{r}_\alpha(t))$, and $\bar{\Psi} s^{(\alpha)} = \Psi(\vec{s}_\alpha)$, the energy loss rate is given by

$$\frac{dE_\alpha}{dx} = m_\alpha (\sum_i a_j s_{\alpha,i} + \frac{1}{2} \sum_i b_{ij}) \quad (28)$$

that is with into consideration \vec{r} and \vec{s} after integration energy of $E_\alpha = \frac{1}{2} m_\alpha v_\alpha^2$. For more evaluation a_i and b_{ij} have calculated on consideration coulomb scattering giving and they must be substituted as function for s_i Rosenbluth *et al* [24]

$$a_j = \Gamma \partial / \partial s_i (L(\vec{s})) \quad (29)$$

$$b_{ij} = \Gamma \partial^2 / \partial s_i \partial s_j (g(\vec{s})) \quad (30)$$

Where

$$L(\vec{s}) = (1 + m_\alpha / m_e) \int d^3\vec{s}^- F_e(\vec{s}^-) 1/|\vec{s} - \vec{s}^-| \quad (31)$$

$$g(\vec{s}) = \int d^3\vec{s}^- F_e(\vec{s}^-) |\vec{s} - \vec{s}^-| \quad (32)$$

$$\Gamma = (4\pi e^4 q^2 / m_\alpha^2) \ln \Lambda \quad (33)$$

Where q for alpha particle is (2) and Λ is coulomb logarithm

$$\Lambda = \frac{3}{2} K_B T \left(\frac{\lambda_D}{e^2} \right) = \frac{3}{2} (K_B T / e^2)^{3/2} 1 / \pi N_e \quad (34)$$

where λ_D representing Debye length for distribution of Maxwell - Boltzmann

$$F_e(\vec{s}) = N_e (\beta / \pi)^{3/2} e^{-\beta s^2}, \beta = m_e / 2 K_B T \quad (35)$$

$$\frac{dsp}{dt} = \frac{sdsp}{dx} = \frac{4\pi q^2 e^4}{m_e} (\ln \Lambda) N_e(x) * (2/\sqrt{\pi} (m_e / 2 K_B T)^{1/2}) * \exp\left(-\frac{m_e s^2}{2 K_B T}\right) - 1/s \text{ error function } (m_e / 2 K_B T)^{1/2} . S \quad (36)$$

Scatter an electron without liberation of photons that never occur Ray and Hora [20,21] Have power for alpha particles in Fokker - Planck formalism .symmetric formalism is used by referred to this fact Ray and Hora have used this effect to evaluation of stopping power for alpha particles in Fokker - Planck formalism. Symmetric formalism is used by Devaney and stein [25] for calculation of stopping power. Let suggest multi types $j = 1, 2, 3 \dots j$ where j for electrons is equal (1) and p_i be density of particles per cubic centimeter and τ_i temperature (kev) where $S_0 \geq S$ where S_0 is the primary energy, the Debye length is obtained by

$$\lambda_D = |4\pi e^2 \sum_{j=1}^J p_j q_j^2 / \tau_i|^{-1/2} \quad (37)$$

Where $e^2 = 1.44 \times 10^{-10}$ kev.cm, the coulomb logarithm is obtained by

$$L_i(s) = \log((1 + \Lambda_j^2(s)^{1/2})) \quad (38)$$

$$\Lambda_j(s) = \lambda_D / (m + m_j). (2 m_j s + 3 m \tau_i / q q_j e^2) \quad (39)$$

It can obtain microscopic types stopping

$$w_i(s) = 2\pi q^2 q_j^2 e^4 \left(\frac{m}{m_j} \right) L_i(s) g\left(\left(\frac{m_j s}{m \tau_i}\right)^{1/2}\right) 1/s \quad (40)$$

where

$$g(x) = \text{error function } x - \frac{2}{\sqrt{\pi}} x e^{-x^2} = \frac{2}{\sqrt{\pi}} \left(\int_0^x e^{-y^2} dy - x e^{-x^2} \right) \quad (41)$$

$$dsp(T) = \frac{ds}{dx} = \sum_{j=1}^J p_j w_j(s) \quad (42)$$

this is represent total stopping power, the Range given by

$$R = (S_0 - S) = \int_S^{S_0} \frac{dsp}{dsp(T)} \quad (43)$$

2.4 Stopping power corresponding to nuclear Scattering

The losses of energy to nuclei in this section we have considered because of hadronic elastic scattering and intrusion between hadronic coulomb terms both from scattering of nuclear coulomb intrusion plus elastic scattering for nuclear force independent of density and temperature. the charged particles are scattered as the coulomb scattering by nuclei and electrons and it is very important to evaluate terms of loss of energy per trajectory length due to it is peaked in front trend strongly despite the hadronic and nuclei scattering do not like particles



maybe be in Rear trend is great because that its Contribution lead to no straight trajectory with this the loss of energy per unit trajectory length we continue to calculate that and calculate range of a straight-line the simplify approximation in the results must take into account Brueckner and Sorna [26] have pointed to quantity very significant for burn spread is a magnitude of energy escaping from D-T burning sphere with density and temperature constant by this the burn front promulgation rate is determined when alpha particles cause that this rate determine velocity simply. The alpha particle can heat cold fuel the radius of sphere and range can ordinarily be used to calculate fraction of escape energy [27,28,29,30] due to large angle scattering the factual portion of energy escaping have to less Mote Calroltype is treat this that explained in ref [25] for unlike particles

$$(10^{24}/N_a S)(dsp/dx) = 4\pi m_\alpha m_d / (m_\alpha + m_d)^2 \int_{-1}^{+1} \sigma_s^-(r)(1-r)dr \quad (44)$$

where N_a is atoms number per unit volume m_α is alpha particle mass, m_d or m_T represent D or T nuclei mass s is alpha particle energy, x is the travelled distance, $\sigma^-(r)$ the cross - section of variations elastic scattering, $r = \cos\Phi$, Φ angle of scattering for this reason participating with a view to of T ion is 1.44 time as great as D ion participating with a view simulate D-T 50:50 admixture

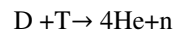
value of deuterium multiply by 1.22 tritium with 4.6 MeV and deuterium with 2.15 MeV we neglect the resonance in the calculation and in ref [25] from Figure-4 we represent $dsp/dx|_{nuc}$ as

$$\begin{aligned} 1/\rho)(dsp/dx) &= (1/\rho)(N_a/10^{24}).S.Q \\ S &> 0.8 \text{ MeV} \\ \left(\frac{1}{\rho}\right)\left(\frac{dsp}{dx}\right) &= 0 \quad S < 0.8 \text{ MeV} \end{aligned} \quad (45)$$

Where $Q = 0.85$

3. CALCULATIONS AND RESULT

Our calculations are concentrated on the energy lossor sometimes called the stopping power for heavy ions (alpha particles) in hot plasma, i.e. in the common thermonuclear fusion reaction which represented as follow:



Calculation for the stopping power due to the heavy ion contribution are completely describe by formulas [2,45]. Our result for the ion stopping power dependence upon the energies and the Range for the alpha particles is tabulated in Table-1.

**Table-1.** Stopping power characteristics factors for heavy ion in (D-T) plasma.

Results of R and SP		Results of E and SP		Results of E and R	
Range (mg.cm ⁻²)	SP*(10 ⁻² KeV.cm ² .g ⁻¹)	E (MeV)	SP*(10 ⁻² KeV.cm ² .g ⁻¹)	E (MeV)	Range (mg.cm ⁻²)
1.09	7.36	0.2018	0.756	0.202	8.33
16	7.92	0.2613	15.1	0.315	13.6
33.2	7.92	0.3474	37.1	0.477	20.2
48.1	9.06	0.4003	48.4	0.598	25.9
68.7	9.06	0.4598	65	0.736	31.6
88.2	9.62	0.5425	86.2	0.881	37.7
98.5	11.3	0.6054	99.8	1.04	44.7
113	10.8	0.7013	115	1.24	53.1
133	11.9	0.8469	136	1.41	60.1
149	14.2	0.956	150	1.55	66.7
165	14.2	1.042	163	1.71	73.2
187	16.4	1.181	180	1.88	80.3
198	18.1	1.284	193	2.01	86.4
211	18.7	1.346	200	2.16	92.5
236	22.1	1.462	213	2.31	99.1
249	23.8	1.601	228	2.42	104
265	27.7	1.72	241	2.55	110
284	33.4	1.806	250	2.68	115
299	37.4	1.886	259	2.81	121
311	42.5	2.061	276	2.96	127
323	50.4	2.183	288	3.06	131
329	56	2.293	299	3.16	136
336	64.5	2.385	309	3.27	140
342	72.5	2.498	320	3.36	144
347	82.6	2.699	340	3.44	147
349	91.7	2.792	350	3.5	150
353	101	2.994	364		
356	114	3.219	380		
359	147	3.49	400		

And the physical behaviors for variation the stopping power with the penetrating factor (Range) and

with the energies for alpha particles are describe in Figures 1 and 2

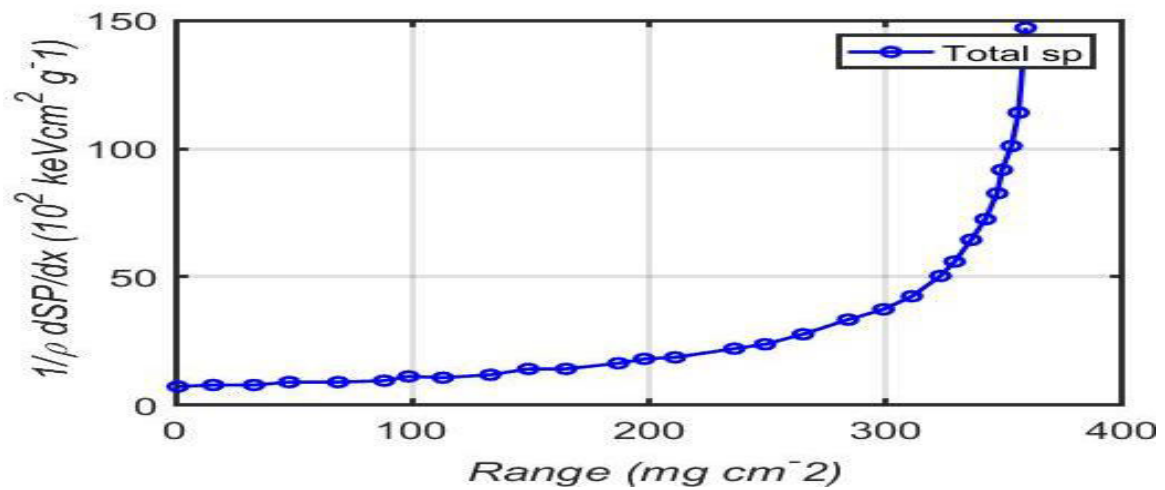


Figure-1. The variation of ion stopping power with their ion range.

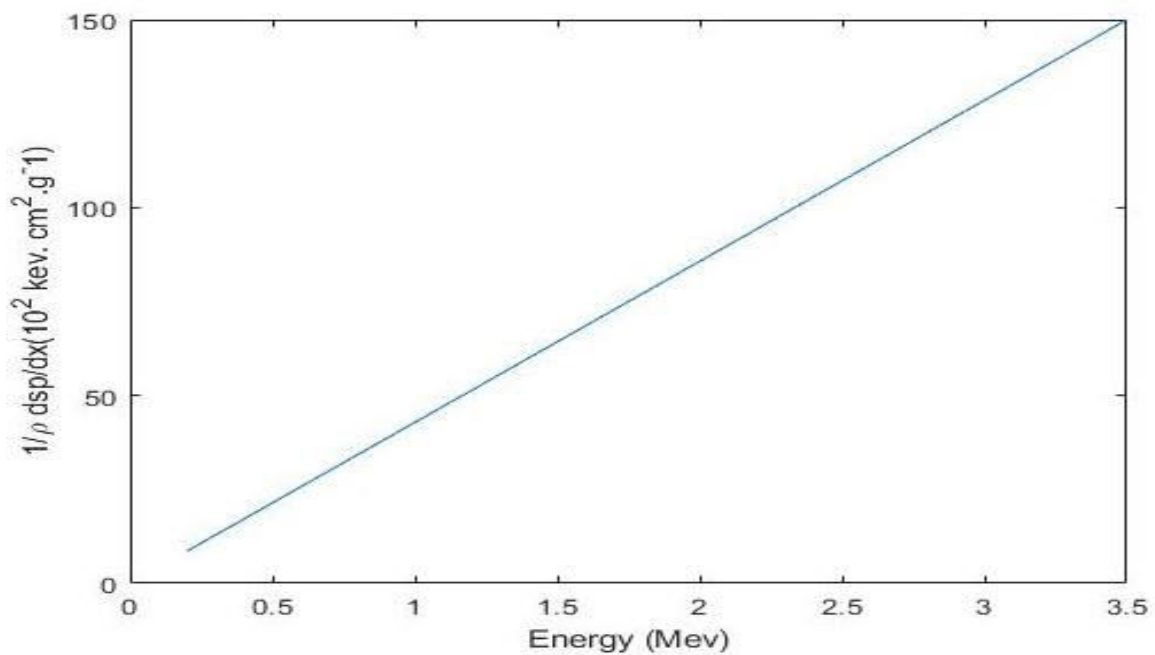


Figure-2. The variation of stopping power of ions with their corresponding energy.

The dependence of the penetrating ability for alpha particles on its energy is describe in Figure-3

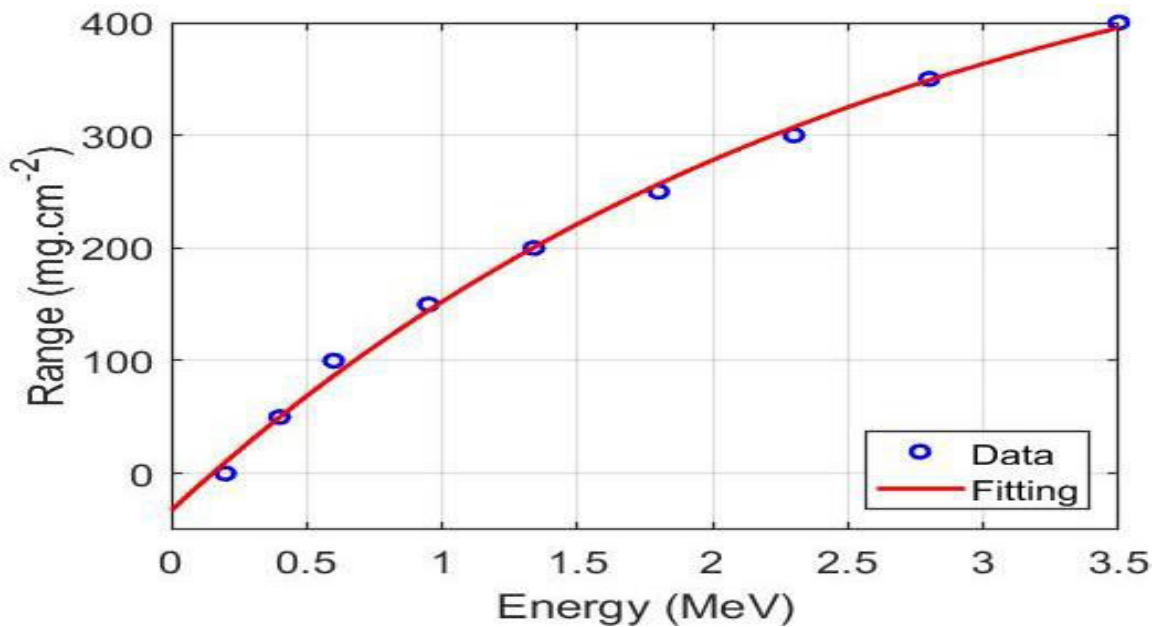


Figure-3. Variation the ion range with their corresponding Energy.

4. DISCUSSION AND CONCLUSIONS

From figure one, which describe the energy loss or the stopping power profiles with the heavy ion penetrating through the fells matter. we can note that the nonlinear increasing beehives for the stopping power as a result for increasing penetrating ability, and this behavior is reflects the physical facts that means the directly dependence between the two factors.

The optimum non leaner relationship between the stopping power and the Range for heavy ion contribution maybe be produce by using a least - square fitting technique program and represented by the following:

$$\text{Equation} = y = y_0 + A_1 \cdot \exp((x - x_0)/t_1) + A_2 \cdot \exp((x - x_0)/t_2)$$

where

$$y_0 = 8.13772, x_0 = 207.86871, A_1 = 4.29155 \times 10^{-7}, t_1 = 8.01377, A_2 = 9.36105, t_2 = 75.76383$$

From Figure two, which explain the variation of the stopping power as function of the alpha particles energies (heavy ions)?we can concluded that the linear increasing for the stopping power with energy increasing and this dependence is basic fundamental known physical phenomena which means every fast particles will

penetrate or diffuse more than more in the matter. i.e. particles will have high stopping power in the matter the fitting relationship between the stopping power and the heavy ion energies is given by the following formula:

$$\text{Equation} = y = a + b \cdot x$$

$$\text{Intercept} = -0.04191, \text{Slope} = 42.90668$$

From Figure-3, which explain the physical variation for the ion penetrating profile with or as the ion energies increasing and it is clearly appear the huge possibility for penetrating for fast ion through the matter. The corresponding fitting formula related between the Range for ions and its energies is giving by the following formula:

$$\text{Equation} y = y_0 + A \cdot \exp(-0.5 \cdot ((x - x_c)/W)^2)$$

Where

$$y_0 = -478055.31412, x_c = 4.66114, W = 108.92366, A = 478474.22008$$

Finally one can be bring conclusion indicating that we choose a more suitable appropriate heretical approximation that has excellent compatibles with the corresponding experimental published results as described by Figure-4 [25].

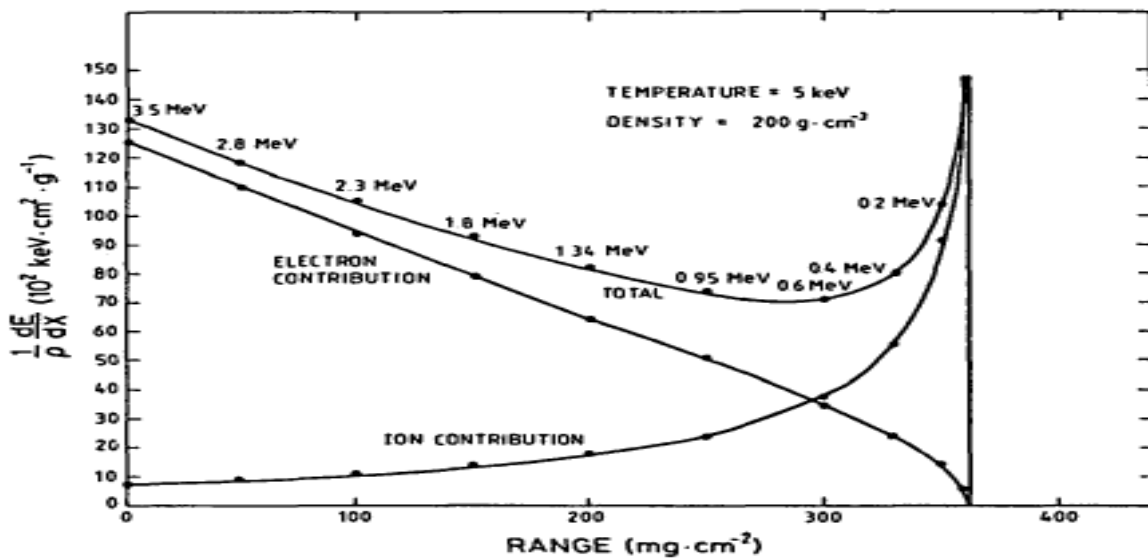


Figure-4. Energy loss of an alpha particle to ions and electrons in D -T at 5 KeV and 200 g.cm⁻³

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