A New Approach to Calculate Mean Charged Multiplicity For Proton – Nucleus Collisions Upto 1 TeV

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Abstract

The theoretical study of energy dependence of charged multiplicity could discriminate among the different theoretical models of particle production. In the present work, an attempt has been made to analyse the data on mean charged multiplicity in Hadron-Nucleus Collisions and also to modify the earlier parameterization with modified values of different parameters on the basis of some unambiguous phenomenon. The mean charged multiplicity has been calculated at different energies, ranging between 1.0 GeV to 1000 GeV for proton-nucleus collisions and the results are compared with experimental data as well as, with other theoretical results. Proposed parameterization is found to be capable of predicting the entire data.

Keywords: *Mean Charged Multiplicity, Proton-Proton, Proton-Nucleus, Hadron-Hadron and Hadron-Nucleus.*

Introduction

During last several years, the Hadron-Hadron [1-5] and Hadron-Nucleus [6-10] interactions have been attracting considerable attention of high energy physicists. In the field of high energy physics, the mean charged Hadron multiplicity has been an important phenomenological parameter to study the properties of particle production. During last few decades, a considerable amount of the data on mean charged multiplicities has become available at high energies [11-18]. And the theoretical studies of energy dependence of charged multiplicity could discriminate among the different theoretical models of particle production [12-16].

The concept of multiplicity arises from the production in the inelastic events of interaction process. To predict the experimental data, several authors [19-22] have proposed different parameterizations and fittings of charged multiplicity as a function of centre of mass (c.m.) energy (√s). At high energies, the concept of secondary production reveals, that the number of relativistic charged particles, produced in any collision, increases as the incoming beam energy increases. The available data [11-13, 16] on multiplicities as a function of energy indicates that at high energies, the mean charged multiplicity $\langle n_{ch} \rangle$ in different Hadron-Nucleus collisions tends to become independent of the type and the charge of the incident and target particles. This behavior of $\langle n_{ch} \rangle$ seems to be valid also at lower energies and also for photon-Hadron [17-19], lepton-Hadron [23-24] and lepton-lepton [19-21] collisions. Thus it would seem that the entire mean charged multiplicities will follow a universal curve.

Present Parameterization

An analysis of the available data on mean charged multiplicity has been considered, in the present work, with a view to finding whether,

i) The mean charged multiplicity $\langle n_{ch} \rangle$ data can be parameterized low as well as at high values of the energy, by the same parameterization.

ii) Each term may explain the related physical concept or phenomena of interaction process. For it, we have considered that all the parameters A, B, C and D should be energy dependent so that they may be consistent with the associated phenomenology.

iii) Any regular feature of mean charged multiplicity $\langle n_{ch} \rangle$ as a function of c.m. energy may be inferred.

The present parameterization for mean charged multiplicity in Hadron-Nucleus Collisions has the following form,

$$< n_s >_{hA} = \upsilon\left[A + B\,ln\left(\frac{\sqrt{s_A}}{\upsilon}\right) + C\left\{ln\left(\frac{\sqrt{s_A}}{\upsilon}\right)\right\}^2 + D\left\{ln\left(\frac{\sqrt{s_A}}{\upsilon}\right)^3\right\}\right] \quad \text{------ (1)}$$

Here $\sqrt{S_A}$ represents the available centre of mass energy (i.e. $\sqrt{S_A} = \sqrt{S} - m_p - m_t$), $\sqrt{S}$ the centre of mass energy, m_p the mass of projectile and m_t the mass of target nucleus. The different terms of the above Eqn. (1) signifies their individual contributions viz. the first term i.e. (υA) gives the charged multiplicity even at threshold energy. The second term i.e. $\left[\upsilon\, B\left(ln\frac{\sqrt{s_A}}{\upsilon}\right)\right]$ represents the contribution due to direct interaction process, while the third term i.e. $\left[\upsilon\, C\left\{ln\left(\frac{\sqrt{s_A}}{\upsilon}\right)\right\}^2\right]$ gives the contribution due to fire-ball formlism in the interaction processes. And finally the fourth term i.e. $\left[\upsilon\, D\left\{ln\left(\frac{\sqrt{s_A}}{\upsilon}\right)\right\}^3\right]$ represents the contribution of Cascade process between projectile hadron and the nucleons of the target nucleus, participating in the interacting process. The parameters υ, A, B, C and D have different values depending upon the nature of incident hadron. The present parameterization has been used to calculate the mean charged multiplicity $< n_s >_{hA}$ in proton-nucleus collisions processes.

Calculations

In the present paper the calculate value of mean charged multiplicity in the case of Proton – Nucleus Collisions are shown in different tables with the help of eq. (1) and these values shows good agreement with experimental data. A graph is plotted between available c.m. energies and mean charged multiplicity which also shows good agreement with experimental curve.

Table (1): Mean Multiplicity $< n_s >_{pA}$ for light nuclei (CNO) at different c.m. energies.

S.No.	Energy $\sqrt{S_A}$ (GeV)	Parameter (B)	Parameter (C)	Parameter (υ)	$< n_s >_{pA}$ (Present work)	$< n_s >_{pA}$ (mean)	$< n_s >_{pA}$ (Experimental)
1.	1.0	0.52 0.52 0.51	0.17 0.17 0.17	1.844 1.929 2.007	1.37 1.40 1.46	1.41	-
2.	4.0	0.61 0.60 0.60	0.15 0.16 0.16	1.772 1.848 1.918	2.84 2.89 2.93	2.87	-
3.	4.95	0.62 0.61 0.60	0.15 0.15 0.16	1.754 1.827 1.895	3.18 2.23 3.28	3.23	3.0 ± 0.2
4.	10.25	0.80 0.79 0.78	0.14 0.14 0.15	1.664 1.727 1.783	4.95 5.02 5.13	5.03	4.71± 0.34
5.	11.7	0.83 0.83 0.82	0.13 0.14 0.14	1.636 1.695 1.748	5.25 5.42 5.48	5.38	4.78 ± 0.3
6.	13.5	0.86 0.85 0.85	0.12 0.13 0.13	1.554 1.604 1.649	5.47 5.61 5.70	5.59	5.6 ± 0.4
7.	25.0	0.97 0.96 0.96	0.09 0.09 0.09	1.343 1.370 1.395	6.52 6.56 6.64	6.57	6.4 ± 0.23

8.	33.95	0.99 0.99 1.0	0.07 0.08 0.09	1.312 1.337 1.359	6.96 7.19 7.45	7.2	7.4 ± 0.3
9.	50.0	1.03 1.03 1.04	0.06 0.07 0.08	1.263 1.283 1.301	7.7 7.96 8.25	7.79	7.72 ± 0.16
10.	100	1.05 1.08 1.08	0.06 0.07 0.07	1.235 1.253 1.268	9.41 9.91 10.0	9.77	10.5 ± 0.5
11.	150	1.08 1.09 1.10	0.05 0.06 0.07	1.213 1.229 1.243	10.29 10.72 11.16	10.72	10.8 ± 0.6
12.	500	1.10 1.14 1.14	0.05 0.05 0.06	1.174 1.186 1.197	13.75 14.14 14.68	14.19	13.1 ± 1.8
13.	1000	1.14 1.15 1.15	0.05 0.06 0.06	1.170 1.182 1.193	16.44 17.18 17.31	16.98	-

Table (2): Mean Multiplicity $< n_s >_{pA}$ for Inter nuclei (BrAg) at different c.m. energies.

S.No.	Energy $\sqrt{S_A}$ (GeV)	Parameter (B)	Parameter (C)	Parameter (υ)	$< n_s >_{pA}$ (Present work)	$< n_s >_{pA}$ (mean)	$< n_s >_{pA}$ (Experimental)
1.	1.0	0.17 0.13	0.18 0.18	3.460 3.844	3.62 4.33	3.98	-
2.	4.0	0.36 0.35	0.16 0.16	3.153 3.475	3.45 3.66	3.56	-
3.	4.95	0.38 0.35	0.16 0.16	3.029 3.321	3.71 3.87	3.79	3.5 ± 0.3
4.	10.25	0.68 0.66	0.15 0.16	2.817 3.069	6.05 6.27	6.16	5.99 ± 0.31
5.	11.7	0.72 0.71	0.14 0.15	2.717 2.951	6.47 6.75	6.61	6.26 ± 0.25
6.	13.5	0.77 0.76	0.14 0.14	2.531 2.733	6.90 7.13	7.02	7.1 ± 0.25
7.	25	0.91 0.91	0.11 0.11	1.995 2.109	8.31 8.59	8.45	9.27 ± 0.43
8.	33.95	0.96 0.95	0.09 0.10	1.9 2.0	9.03 9.43	9.23	11.0 ± 0.03
9.	50	0.99 1.0	0.08 0.09	1.755 1.835	9.86 10.30	10.08	11.0 ± 0.3
10.	100	1.05 1.06	0.08 0.08	1.701 1.774	12.45 12.75	12.6	15.2 ± 0.6
11.	150	1.09 1.09	0.07 0.08	1.675 1.744	13.77 14.52	14.15	16.8 ± 0.45
12.	500	1.13 1.14	0.07 0.08	1.6 1.66	18.80 19.78	19.29	23.1 ± 3.6
13.	1000	1.14 1.15	0.07 0.08	1.557 1.613	21.89 23.05	22.47	-

Table (3): Mean Multiplicity $< n_s >_{pA}$ for Heavy nuclei (PbU) at different c.m. energies.

S.No.	Energy $\sqrt{s_A}$ (GeV)	Parameter (B)	Parameter (C)	Parameter (υ)	$< n_s >_{pA}$ (Present work)	$< n_s >_{pA}$ (mean)	$< n_s >_{pA}$ (Experimental)
1.	1.0	0.07 0.06	0.18 0.18	5.172 5.451	6.87 7.46	7.17	-
2.	4.0	0.16 0.17	0.16 0.16	4.545 4.771	4.47 4.65	4.56	-
3.	4.95	0.17 0.17	0.16 0.16	4.1 4.5	4.25 4.58	4.42	-
4.	10.25	0.60 0.60	0.15 0.16	3.911 3.984	6.74 6.93	6.84	-
5.	11.7	0.65 0.65	0.15 0.15	3.734 3.894	7.29 7.44	7.37	-
6.	13.5	0.70 0.70	0.14 0.15	3.566 3.894	7.85 8.26	8.06	-
7.	25	0.87 0.85	0.12 0.13	2.726 2.814	9.88 10.07	9.98	11.67± 0.57
8.	33.95	0.92 0.90	0.11 0.12	2.555 2.814	10.96 11.65	11.31	-
9.	50	0.98 0.98	0.10 0.11	2.397 2.463	12.41 12.85	12.63	14.75 ± 0.38
10.	100	1.04 1.03	0.10 0.10	2.3 2.359	15.83 16.01	15.92	18.47 ± 0.4
11.	150	1.07 1.06	0.09 0.10	2.205 2.260	17.35 17.95	17.65	18.6 ± 1.5
12.	500	1.13 1.13	0.09 0.09	2.117 2.166	24.33 24.74	24.54	-
13.	1000	1.14 1.14	0.08 0.09	2.016 2.06	27.31 28.54	27.93	-

Result and Discussion

The calculation of mean charged multiplicity $< n_{ch} >_{pA}$ in proton-nucleus interactions is done on the basis of Eqn. (1) here we have proposed, the different values of the parameters A, B, C, D and υ, to be depending upon the nature of incident hadron. For p-nucleus interactions the values of parameters A = 1 (constant), D = 0.01 the Cascade coefficient, B and C to be energy dependent and the values of υ are calculated by Geometrical Wounded model [9]

In the case of hadron-nucleus collisions, the nuclei are classified in three different groups viz., the light nuclei, consisting Carbon, Nitrogen and Oxygen (CNO), the intermediate nuclei, consisting Silver and Bromine (AgBr) and the heavy nuclei, consisting of Lead and Uranium (PbU). In the present work, we have calculated the mean normalized multiplicity also and have compared it by different parameterizations, given by different authors.

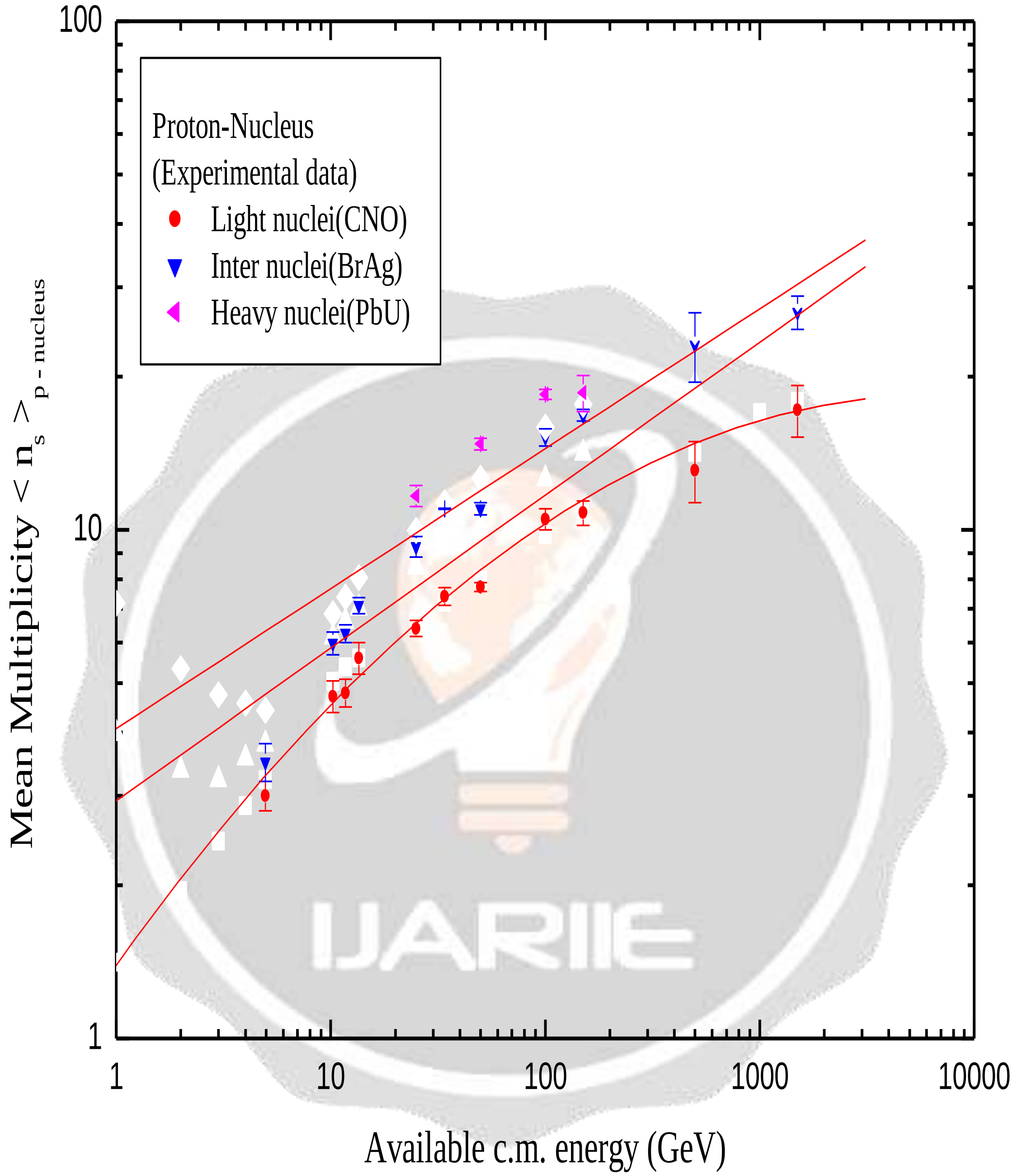
Conclusion

On the basis of the present analysis, the following conclusions may be drawn.

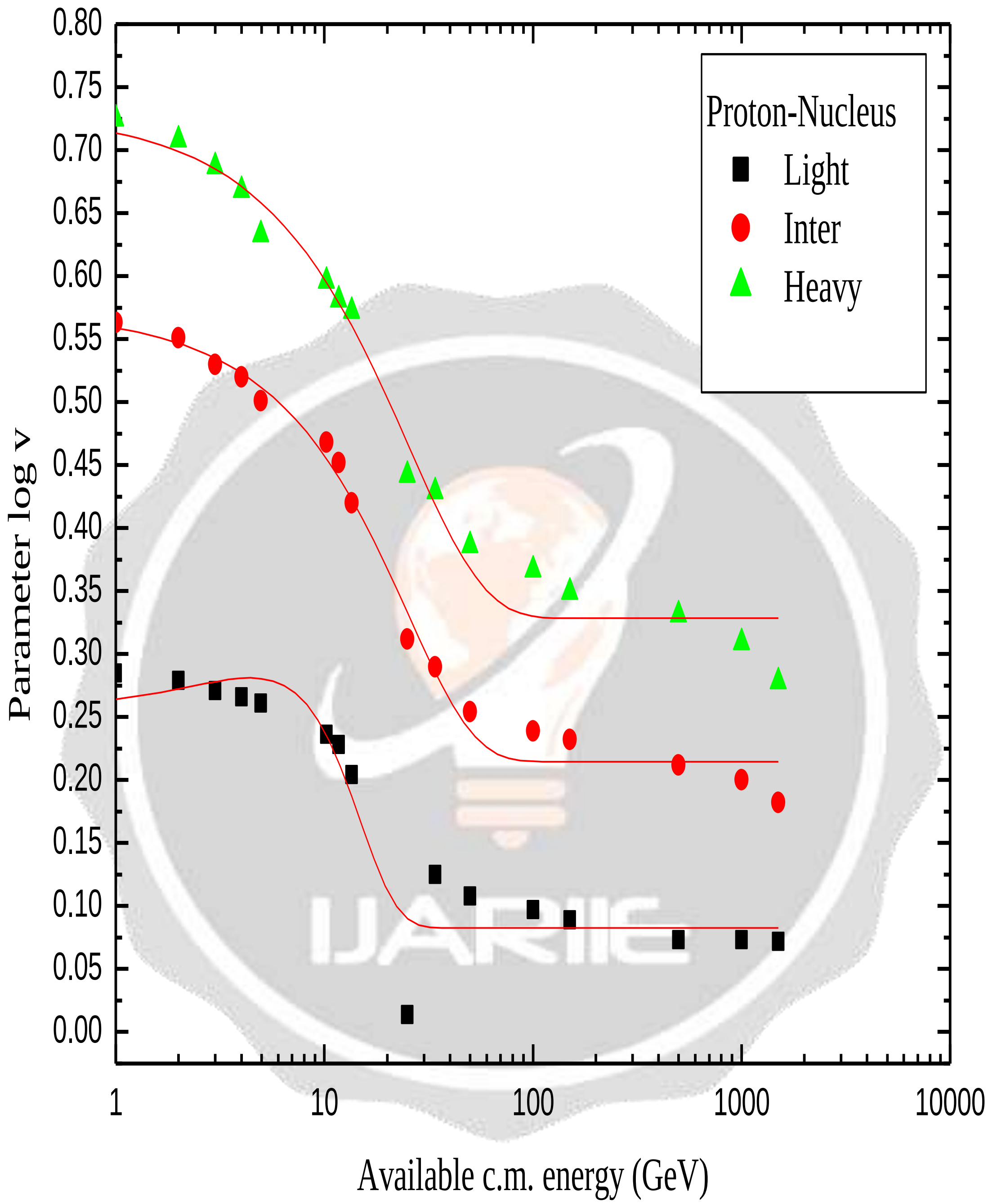
(1) The present parameterization of mean charged multiplicity $< n_{ch} >_{hA}$ in hadron-nucleus collisions provides simple and unambiguous results, which are in well consistent with experimental data for the entire range of incident energy.

(2) Mean charged multiplicity $< n_s >_{hA}$ in hadron-nucleus is dependent of the available c.m. energy i.e. due to limited nucleons (υ), not on the total c.m. energy.

(3) The variation of running coupling constant α_s with energy and nuclear mass and consequently the variation of 'υ' with energy as well as with target size, provides fruitful results.



Graph (1): **Variation of mean charged multiplicity with available c.m. energy.**



Graph (2): **Variation of parameter (υ) with available c.m. energy.**

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