A COMPARATIVE STUDY OF ENERGY DEPENDENCE PARAMETER AS MEAN CHARGED MULTIPLICITY FOR HADRON HADRON INTERACTIONS

HARDIK P. TRIVEDI[1*] AND R.K.PALIWAL [2]

[1] *Research Scholar, Faculty of Science and Technology, Department of Physics, Mewar University, Chittorgarh (Raj.) India*

[2] *Professor, Faculty of Science and Technology, Department of Physics, Mewar University, Chittorgarh (Raj.) India*

ABSTRACT

In the present work an attempt is made to analyses the experimental as well as theoretical observations on Mean Charged Multiplicities at various energies in hadron- hadron interactions. The mean charged multiplicity has been calculated for energies between 2 GeV to 7000 GeV for Proton-Proton interactions and between 1 GeV to 7000 GeV for Proton-Antiproton interactions, also the results are compared with experimental data as well as, with other theoretical results.

Key word: *Mean Charged Multiplicity, Proton-Proton, Proton-Antiproton and Hadron-Hadron*

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1. Introduction:

During last two or three decades, the hadron-hadron [1-4] interaction has been attracting attention of high energy physicists. In the field of high energy physics, the mean charged multiplicity has been an important parameter to study the properties of particle production. For the explanation of particle production several theoretical models have been suggested by different authors [5-7]. The high energy physics deals basically with the study of the inner most structure of the matter i.e. nucleus. When an energetic particle (i.e. hadrons) collides with the target, the target breaks up into a number of charged and uncharged particles. Such interaction processes are energy dependent, as well as impact parameter dependent. In the high energy interaction processes, the production of multiparticle has become the most important phenomenon in the present days. During last few decades, a considerable amount of the data on mean charged multiplicities has become available with different groups of scientists of CERN [8, 9], FERMILAB [10, 11] and SLAC [12, 13] etc. The available data [14-17] on multiplicities as a function of energy indicates that at high energies, the mean charged multiplicity $\langle n_{ch} \rangle$ for hadron- hadron interactions tends to become independent of the type and the charge of the incident and target particles. Thus it would seem that the entire mean charged multiplicities will follow a universal curve. In the present work, an attempt has been made to analyse the experimental observations on mean charged multiplicity at various energies ranges for hadron- hadron interactions. Different parameterizations proposed by different authors, have been studied and an effort is done to modify the earlier parameterization [18-25]. The values of different parameters have been fixed on the basis of some unambiguous phenomenon. The present parameterization has been used to calculate the mean charged multiplicity as a function of incident c.m. energy for hadron- hadron.

2. Parameterization:

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

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

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

c) Any regular feature of mean charged multiplicity $<n_{ch}>$ as a function of c.m. energy may be inferred on the concerned interaction process. The present parameterization for mean charged multiplicity in hadron-hadron interaction has the following form,

$<n_{ch}>_{hh} = A + B \ln\sqrt{S_A} + C (\ln\sqrt{S_A})^2$ -------------------------------(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 values of the parameters A, B and C are considered on the basis of interaction process. The different terms of the above equation signifies their individual contribution, viz. the first term {i.e. A} gives the mean charged multiplicity {$<n_{ch}>$ }, even at threshold energy of particle production in hadronic interaction {i.e. 1GeV}. Since the particle production in any interaction is the result of the formation of quark-gluon plasma and this state is found near 1 GeV interaction energy, therefore the minimum charged multiplicity, in charged hadronic interactions may be two. The second term {i.e. B ln $\sqrt{S_A}$} represents the contribution due to direct interaction process. The value of parameter B is considered, in this work, to be dependent on the ratio ρ of the real to the imaginary part of the coulomb amplitude, which is related with the total and scattering cross-section as $\rho = \frac{\sigma_{tot}}{\sigma_{el}}$ and is energy dependent. The parameter B is related with by the relation B = (1+ρ). The various values of at different c.m. energies may be obtained by its above relation with σ_{tot} and σ_{el}[26-27], as shown in Fig.2 for proton-proton and proton-antiproton interactions. And finally the third term {i.e. C (ln $\sqrt{S_A}$)^2} gives the contribution due to fire-ball formalism in the interaction process. The value of parameter C is considered, in the present work, to be dependent on the absorption coefficient as C = = 0.4246 α_s [25] where = 3.14 also = α_s[(1- α) where α is inelastic coefficient and has different values at different incident energies. The different parameters are supposed to have their origins from Quantum Chromodynamics (QCD). For the various values of α at different c.m. energies, we have used our earlier work [28] to obtain the different values of the parameter C.

3. Result and Discussion:

The mean charged multiplicities $<n_{ch}>_{pp}$ for proton- proton and $<n_{ch}>_{pp-}$ are calculated in the present work at energies ranges from 1 GeV to 7000 GeV using present parameterization through equation (1). Calculated mean charged multiplicities for proton-proton and proton- antiproton interactions are given in table 1 and table 2 respectively. This mean charged multiplicities are plotted in fig 1. The results of the present parameterization are well in consistent with the experimental data. A slight deviation of experimental data from the proposed fitting is due to some experimental errors. In the present work, we have proposed the values of the parameters B and C to be energy dependent. The variation of the parameter B and C with c.m. energy are shown in fig. 2 and fig.3 for proton-proton and proton-antiproton interactions.

Table (1) : Mean Charged Multiplicity $< n_{ch} >_{pp}$ at different centre of mass energies in the case of proton-proton interactions. Here parameters A = 2, B and C are calculated as a function of c.m. energy.

S.No.	Energy $\sqrt{S_A}$ (GeV)	Parameter (B)	Parameter (C)	Parameter (α_s)	$< n_{ch} >_{pp}$ (Present work)	$< n_{ch} >_{pp}$ (Experimental)
1.	2	0.73	0.17	0.40	2.59	2.18 ± 0.09
2.	3	0.74	0.16	0.38	3.01	2.54 ± 0.03
3.	3.08	0.74	0.16	0.38	3.03	2.54 ± 0.03
4.	3.5	0.74	0.16	0.38	3.18	2.71 ± 0.01
5.	3.65	0.74	0.16	0.38	3.23	2.94 ± 0.03
6	3.78	0.74	0.16	0.38	3.27	2.85 ± 0.03

7.	4	0.74	0.16	0.38	3.33	2.85 ± 0.03
8.	4.53	0.74	0.16	0.38	3.48	3.24 ± 0.03
9.	4.54	0.74	0.16	0.38	3.49	3.22 ± 0.06
10.	4.93	0.75	0.15	0.38	3.58	3.43 ± 0.03
11.	4.95	0.75	0.15	0.35	3.58	3.04 ± 0.03
12.	5.1	0.75	0.15	0.35	3.62	3.58 ± 0.05
13.	5.64	0.76	0.15	0.35	3.76	3.92 ± 0.11
14.	5.97	0.76	0.15	0.35	3.84	3.91 ± 0.06
15.	6.12	0.78	0.15	0.35	3.91	4.02 ± 0.02
16.	6.3	0.78	0.15	0.35	3.94	4.10 ± 0.04
17.	6.43	0.78	0.15	0.35	3.97	4.11 ± 0.06
18.	6.63	0.78	0.15	0.35	4.01	4.22 ± 0.04
19.	6.84	0.78	0.15	0.35	4.05	4.23 ± 0.15
20.	6.84	0.78	0.15	0.35	4.05	4.25 ± 0.03
21.	6.85	0.78	0.15	0.35	4.06	4.31 ± 0.06
22.	7.24	0.79	0.15	0.35	4.15	4.41 ± 0.04
23.	7.36	0.79	0.15	0.35	4.17	4.46 ± 0.04
24.	7.42	0.79	0.15	0.35	4.19	4.37 ± 0.07
25.	7.43	0.79	0.15	0.35	4.19	4.52 ± 0.07
26.	8.21	0.82	0.15	0.35	4.39	5.01 ± 0.08
27.	9.78	0.83	0.14	0.35	4.62	5.35 ± 0.11
28.	10.25	0.83	0.14	0.32	4.69	4.11 ± 0.04
29.	11.5	0.86	0.13	0.30	4.88	5.89 ± 0.07
30.	11.7	0.86	0.13	0.30	4.90	4.22 ± 0.04
31.	13.5	0.88	0.11	0.27	5.04	4.41 ± 0.04
32.	13.8	0.88	0.11	0.27	5.07	6.49 ± 0.10
33.	13.9	0.88	0.11	0.27	5.08	6.32 ± 0.07
34.	19.4	0.9	0.11	0.24	5.64	7.64 ± 0.17
35.	19.4	0.9	0.11	0.24	5.64	8.20 ± 0.20
36.	19.6	0.92	0.11	0.24	5.71	7.68 ± 0.07
37.	21.7	0.92	0.11	0.21	5.87	8.80 ± 1.9
38.	23.3	0.93	0.11	0.20	6.02	9.24 ± 0.92
39.	23.7	0.93	0.11	0.20	6.05	9.00 ± 1.0
40.	23.9	0.94	0.08	0.20	5.79	8.50 ± 0.12
41.	25	0.97	0.08	0.19	5.95	5.42 ± 0.2
42.	25.7	0.97	0.08	0.19	5.99	8.99±0.14
43.	31.8	0.99	0.07	0.18	6.26	10.1±1.0
44.	33.95	1	0.07	0.17	6.39	6.4 ± 0.2
45.	43.3	1.02	0.07	0.16	6.84	10.6 ± 0.60
46.	44.6	1.02	0.06	016	6.74	11.0 ± 1.1
47.	49.4	1.04	0.06	0.15	6.97	11.0 ± 2.0
48.	50	1.04	0.06	0.14	6.99	6.4 ± 0.06
49.	53	1.04	0.06	0.14	7.07	11.5 ± 1.1
50.	75	1.05	0.06	0.14	7.65	12.6 ± 0.70
51.	100	1.09	0.05	0.12	8.08	7.65 ± 0.17
52.	123	1.09	0.05	0.12	8.40	14.4 ± 0.80
53.	127	1.1	0.05	0.12	8.50	16.3 ± 1.1
54.	143	1.12	0.05	0.11	8.79	18.8 ± 3.0
55.	150	1.12	0.05	0.11	8.87	8.86 ± 0.16
56.	152	1.12	0.05	0.11	8.89	16.0 ± 3.0
57.	200	1.12	0.05	0.11	9.34	8.99 ± 0.14
58.	500	1.14	0.04	0.10	10.63	10.6 ± 0.6
59.	900	1.15	0.04	0.10	11.67	17.9 ± 0.1

60.	1000	1.15	0.04	0.10	11.85	11.5 ± 1.1
61.	1500	1.16	0.03	0.07	12.09	12.6 ± 0.7
62.	2360	1.35	0.03	0.05	14.29	22.9± 0.5
63	3000	1.43	0.03	0.05	15.37	-
64	4000	1.59	0.02	0.05	16.56	-
65	5000	1.72	0.02	0.04	18.10	-
66	6000	1.89	0.02	0.04	19.96	-
67.	7000	2.83	0.02	0.03	28.62	30.4± 0.2

Table (2) : Mean Charged Multiplicity $< n_{ch} >_{p\bar{p}}$ at different centre of mass energies in the case of proton-antiproton interactions. Here parameters A = 2, B and C are calculated as a function of c.m. energy.

S.No.	Energy $\sqrt{s_A}$ (GeV)	Parameter (B)	Parameter (C)	Parameter (α_s)	$< n_{ch} >_{pp-}$ (Present work)	$< n_{ch} >_{pp-}$ (Experimental)
1.	1.0	0.80	0.66	0.39	2	-
2.	2.0	0.81	0.65	0.38	2.87	2.9 ± 0.20
3.	2.86	0.97	0.52	0.38	3.59	2.54 ± 0.03
4.	2.99	0.97	0.52	0.38	3.69	3.35 ± 0.03
5.	3.00	0.90	0.64	0.37	3.75	3.4 ± 0.30
6.	3.07	0.90	0.60	0.35	4.31	3.7 ± 0.40
7.	3.25	0.97	0.52	0.35	3.87	3.32 ± 0.03
8.	3.42	0.90	0.61	0.35	4.02	3.64 ± 0.40
9.	3.55	0.98	0.48	0.35	4.01	3.39±0.04
10.	3.84	0.98	0.48	0.35	4.19	3.57±0.05
11.	3.86	0.98	0.48	0.35	4.20	3.47±0.25
12.	4.37	0.98	0.48	0.35	4.49	3.63±0.03
13.	4.93	0.98	0.48	0.35	4.79	3.92±0.1
14.	5.00	0.93	0.57	0.34	4.97	4.05 ± 0.50
15.	5.40	0.98	0.48	0.34	5.02	4.12±0.06
16.	6.60	0.98	0.48	0.34	5.56	4.68±0.06
17.	7.00	1.0	0.55	0.32	6.02	5.05 ± 0.40
18.	7.75	1.0	0.55	0.32	6.35	5.55 ± 0.30
19.	7.86	0.98	0.48	0.32	6.06	4.98 ± 0.09
20.	10.00	1.02	0.55	0.32	7.26	-
21.	13.8	1	0.44	0.32	7.66	6.74 ± 0.04
22.	20	1.08	0.54	0.32	10.07	-
23.	30	1.10	0.53	0.31	11.87	9.8 ± 0.80
24.	50	1.12	0.53	0.31	14.49	-
25.	100	1.12	0.52	0.31	18.18	-
26.	180	1.13	0.52	0.30	21.88	19.5 ± 0.70
27.	300	1.13	0.51	0.30	25.03	-
28.	500	1.14	0.50	0.29	28.38	-
29.	540	1.14	0.50	0.29	28.95	27.8 ± 0.80
30.	900	1.14	0.48	0.28	31.96	31.2 ± 1.1
31.	1000	1.14	0.48	0.28	32.77	-
32.	1500	1.14	0.48	0.28	36.0	-
33.	2000	1.14	0.48	0.28	38.40	-
34.	3000	1.14	0.48	0.27	41.90	-
35.	4000	1.15	0.46	0.27	43.18	-

36.	5000	1.15	0.46	0.26	45.16	-
37.	6000	1.16	0.45	0.26	46.15	-
38.	7000	1.16	0.45	0.26	47.57	-

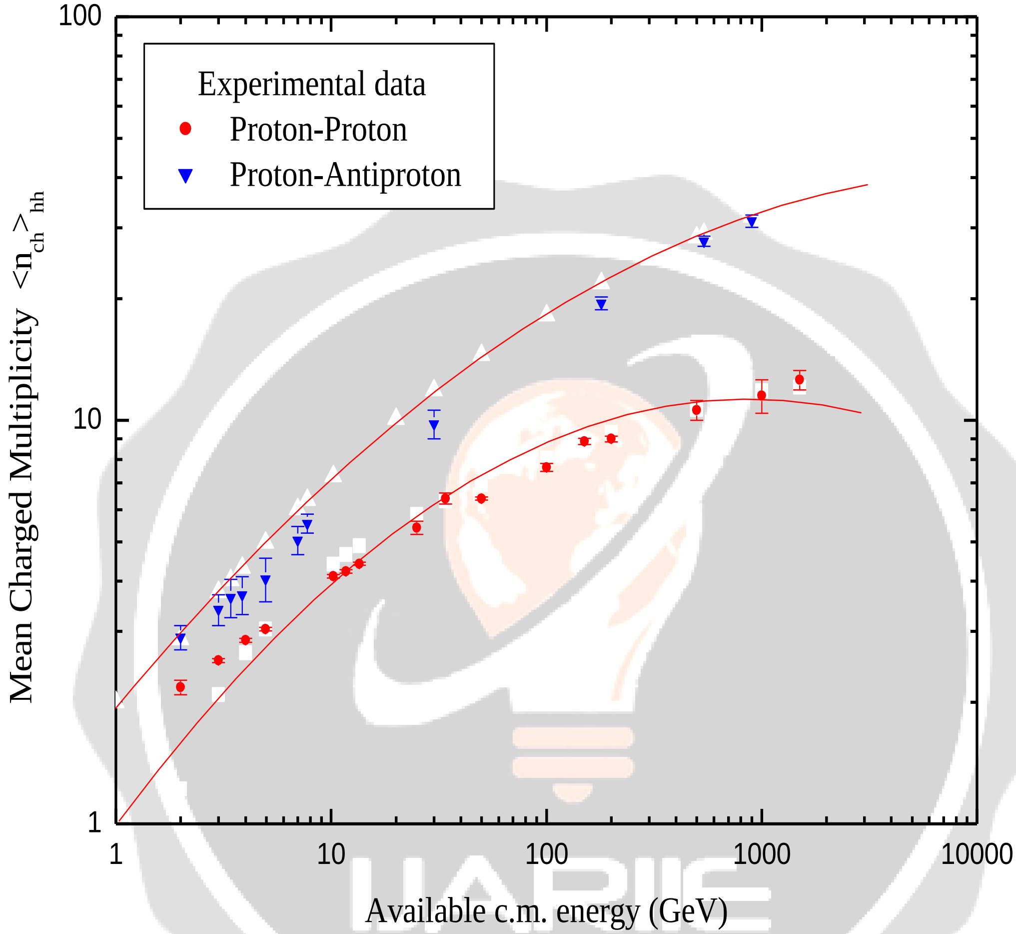

Fig. [1] Mean Charged Multiplicity for Proton-Proton and Proton – Antiproton as a Function of Available Centre of Mass Energy

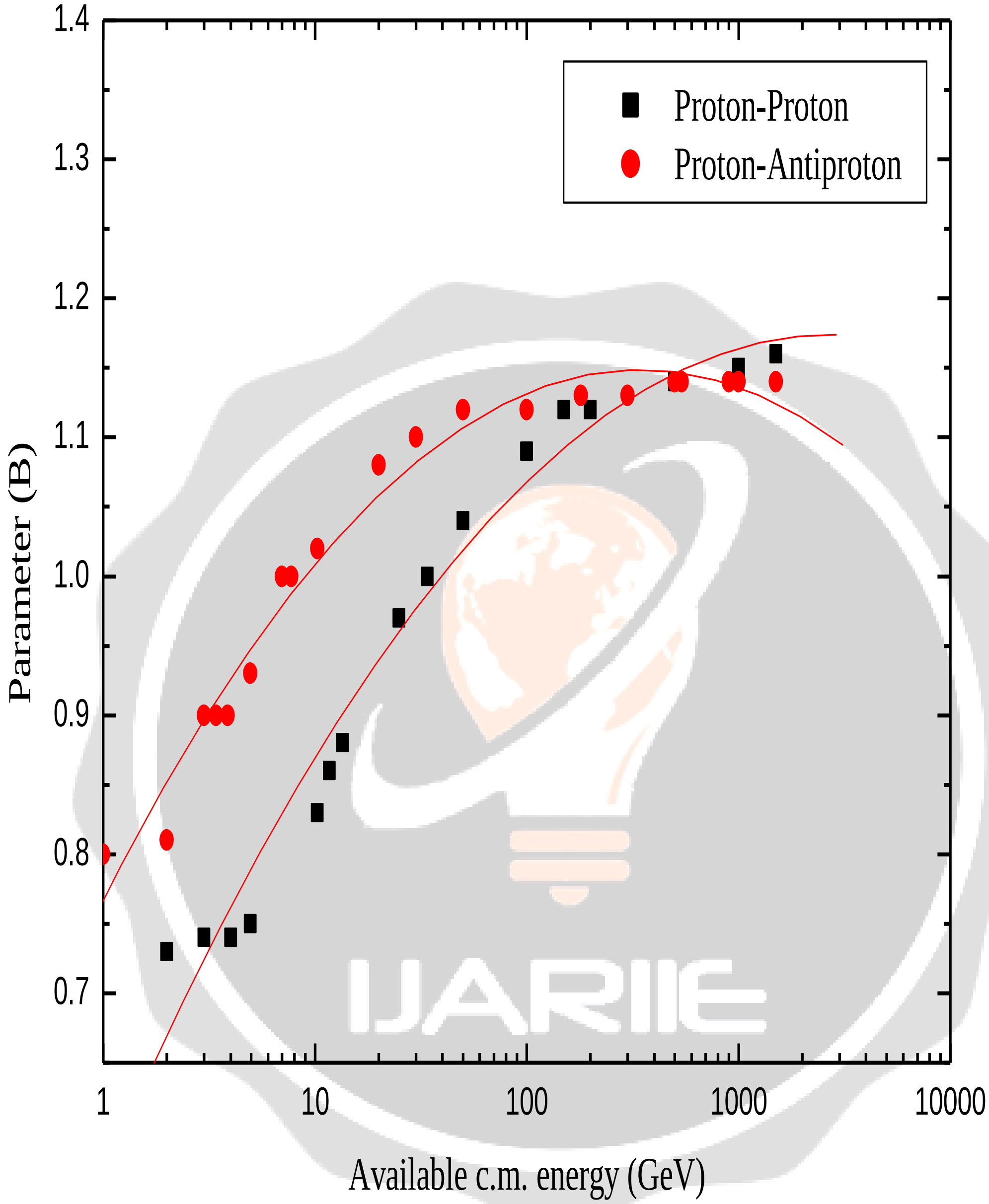

Fig. [2] Variation of Parameter B for Proton – Proton and Proton- Anti Proton Interaction as a Function of Available Centre of Mass Energy

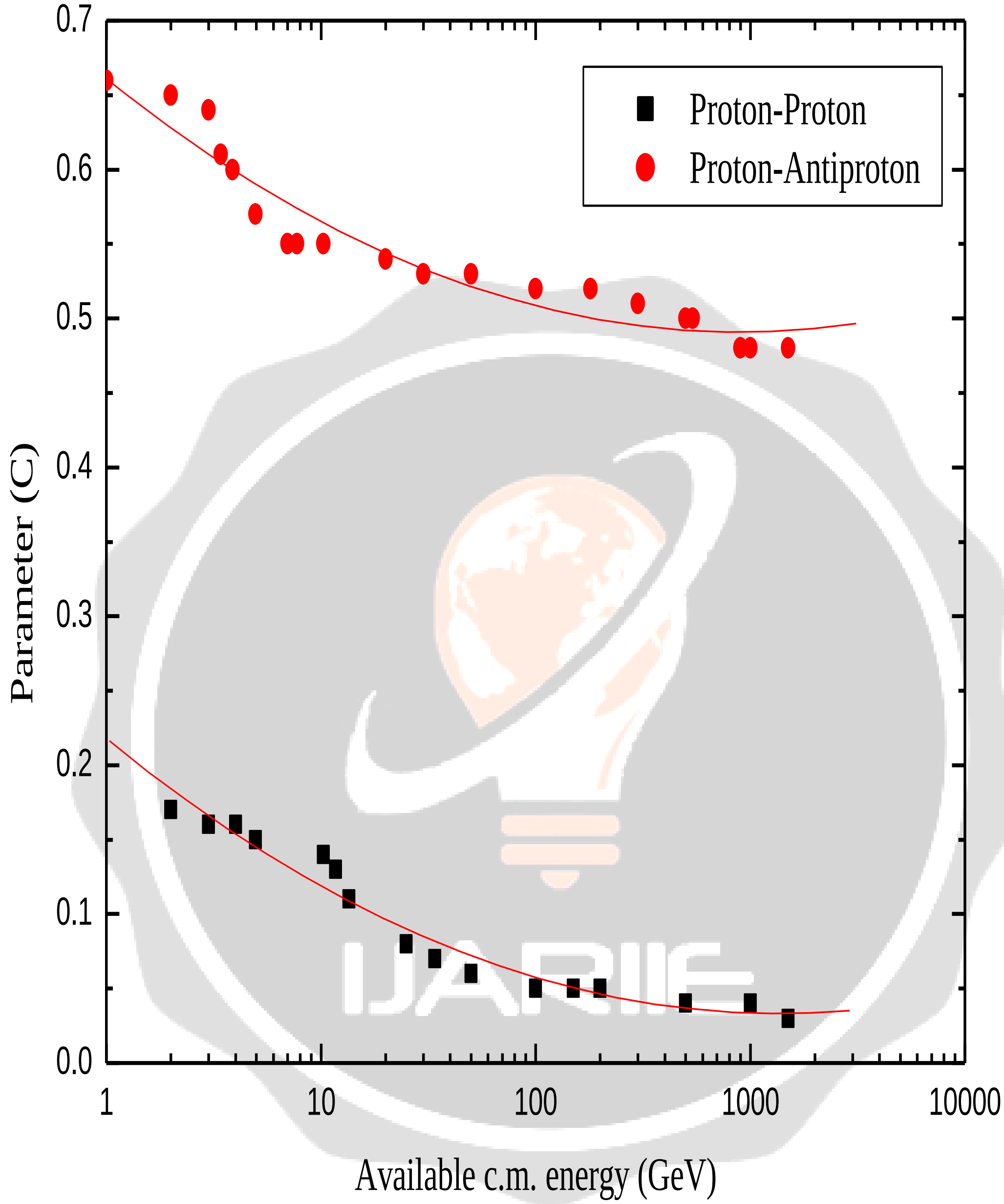

Fig. [3] Variation of Parameter C for Proton – Proton And Proton- Anti Proton Interaction as a Function of Available Centre of Mass Energy

4. CONCLUSIONS:

The following conclusions are found on the basis of present parameterization.

1. The present parameterization of mean charged multiplicity <n_{ch}> for hadron-hadron interactions is found capable to calculate this parameters.
2. The present parameterization is found capable in well consistent with experimental data for the entire range of incident energies.

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Table: 1

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