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AN ESTIMATE OF THE AVERAGE CHARGED MULTIPLICITY AT ISR ENERGIES

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ABSTRACT

By integrating differential rapidity distributions obtained by different groups at the CERN ISR, and assuming a constant total inelastic cross section of 32 mb, we have estimated the average charged multiplicity in pp interactions at four ISR energies.

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Inclusive $\pi^{\pm}$ production spectra [1,2] and angular distributions of all charged secondaries [3] have recently been obtained in high energy pp collisions at the CERN ISR. These data, which cover a c.m. rapidity range from 0.0 to 4.0, allow an estimation of the differential cross sections $d\sigma\,(\pi^{+} + \pi^{-})/dy$ at the four c.m. energies 21.3, 30.4, 44.3 and 52.2 GeV, shown in fig. 1. Numerical integration of these four rapidity curves gives values of the product $\sigma_{inel}\ \langle n_{\pi}\pm\rangle$ which, when kaon and proton production is included, yield average charged multiplicites if σ_{inel} is assumed to be constant [5]. We describe first how we obtained these rapidity curves and afterwards discuss the assumptions involved in estimating the average charged multiplicities.

The π^{+} and π^{-} invariant differential cross sections of refs [1,2] at $p_{\perp} = 0.2$ and $p_{\perp} = 0.4$ GeV/c were converted to values of $(1/2\pi)\ d\sigma/dy$ by integrating over $p_{\perp}$ assuming a $p_{\perp}$ distribution of the form exp $(-\ 6.5\ p_{\perp})$. Cross sections at desired y values were obtained by linear interpolation.

The values of $(1/2\pi)\ d\sigma/dy$ for large y were obtained from the data of ref .[3] by the following procedure. The values of the differential cross sections $d\sigma/d\ (\log \tan \frac{1}{2}\theta)$ were reduced by 15% to subtract kaons and baryons. The resulting differential cross sections were then converted into values of $d\sigma/dy$ using a $p_{\perp}$ parametrization due to Bali [4].

Both procedures were repeated assuming a $p_{\perp}$ distribution of the form exp $(-\ 6\ p_{\perp})$ and the same results were obtained to within 3%.

The rapidity curves plotted in fig. 1 were then integrated numerically to obtain values of the product $\sigma_{inel}\ \langle n_{\pi}\pm\rangle$. The average charged pion multiplicity $\langle n_{\pi}\pm\rangle$ was then calculated taking σ_{inel} to be 32 mb [5]. Assuming a 15 $\pm$ 5% contribution of produced kaons and baryons, and an additional contribution of 1.4 due to leading protons, we obtain the four values of $<n_{ch}>$ shown in table 1 and plotted in fig. 2. The errors quoted are those present in the data of ref. [3].

These values of the average charged multiplicity are compatible with those deduced from a γ-ray production experiment performed at the ISR [6]. The average γ-multiplicity $<n_\gamma>$ was obtained by integrating the production spectra, and assuming that $<n_{ch}> = <n_\gamma> + 1.4$ gives an estimate of the average charged multiplicity. This last step assumes that γ produced by K^o and η^o decay are of the same order as the K and p contribution to the charged data.

The values of $<n_{ch}>$ obtained from bubble chamber data [8-14], from Serpukhov data [15,16] and from cosmic ray data [17-19] are included in table 1 and plotted in fig. 2. Fits were made to the bubble chamber data [10-13,15](*) beginning at 4.54 GeV, and to the ISR data described here. We find the best power fit to be $<n_{ch}> = 7.21\ (E_{c.m.}^{0.245} - 1.00)$ with a χ^2 of 11.6 for 13 degrees of freedom. The best log fit is $<n_{ch}> = -1.09 + 1.42 \ln s$ with a χ^2 of 18.0 for 14 degrees of freedom.

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(*) The bubble chamber points at 6.85 and 7.44 GeV were removed.

REFERENCES

[1] L.G. Ratner, R.J. Ellis, G. Vannini, B.A. Babcock, A.D. Krisch and J.B. Roberts, Phys. Rev. Letters 27 (1971) 68

[2] A. Bertin, P. Capiluppi, A. Cristallini, M. D'Agostino-Bruno, R.J. Ellis, G. Giacomelli, C. Maroni, F. Mercatali, A.M. Rossi and G. Vannini, Phys. Letters 38B (1972) 260

[3] M. Breidenbach, G. Charpak, G. Coignet, D. Drijard, G. Fischer, G. Flügge, Ch. Gottfried, H. Grote, A. Minten, F. Sauli, M. Szeptycka and E.G.H. Williams, Phys. Letters to be published

[4] N.F. Bali, Phys. Letters 25 (1970) 557

[5] G. Barbiellini et al., paper presented at the Oxford Conf. (April, 1972)

[6] G. Neuhofer, F. Niebergall, J. Penzias, M. Regler, W. Schmidt-Parzefall, K.R. Schubert, P.E. Schumacher, M. Steuer and K. Winter, Phys. Letters 38B (1972) 51

[7] K.R. Schubert, Neutral pion production at the ISR, Proc. of the Rencontres de Moriond (March 19, 1972)

[8] L. Bodini, L. Case, J. Kidd, L. Mandelli, V. Pelosi, S. Ratti, V. Russo, L. Tallone, C. Caso, F. Conte, M. Damieri and G. Tomasini, Nuovo Cimento 58A (1968) 475

[9] G. Alexander, O. Benary, G. Czapek, B. Haber, N. Kidron, B. Reuter A. Shapira, E. Simopoulou and G. Yekutieli, Phys. Rev. 154 (1967) 1284;

G. Yekutieli, S. Toaff, A. Shapira, E.E. Ronat, V. Eisenberg, Z. Carmel, G. Alexander, A. Fridman, G. Mauror, J. Oudet, R. Strub, C. Voltolini, P. Cuer and J. Grunhaus, paper submitted to the Vienna Conference on High-Energy Physics (July ,1968)

[10] S.P. Almeida, J.G. Rushbrooke, J.H. Scherenguivel, M. Behrens, V. Blobel, I. Borecka, H.C. Dohne, J. Diaz, G. Knies, A. Schmidt, K. Stromer and W.P. Swanson, Phys. Rev. 174 (1968) 1638

[11] D.B. Smith, R.J. Sprafka and J.A. Anderson, Phys. Rev. Letters, 23 (1969) 1064.

[12] Scandinavian Collaboration, internal report, Niels Bohr Institutet (1969)

[13] P. Dodd, M. Jobes, J. Kinson and B. Tallini, B.R. French, H.J. Sherman and I.O. Skillicorn, W.T. Davies, M. Derrick and D. Radojcic, The Aix-en-Provence Conference on Elementary Particles, Vol. I (1961) 433

[14] W.E. Ellis et al., preprint BNL 14126

[15] Soviet-French Collaboration, paper submitted to the Oxford Conference (April, 1972).

[16] M.G. Antonova et al., paper 263 presented at the Amsterdam Conference(1971)

[17] L.W. Jones, A.E. Bussian, G.D. DeMeester, B.W. Loo, D.E. Lyon Jr., P.V. Ramana Murthy, R.F. Roth, J.G. Learned, F.E. Mills, D.D. Reeder, K.N. Erickson and B. Cork, Phys. Rev. Letters 25 (1970) 1679

[18] L. von Lindern, R.S. Panvini, J. Hanlon and E.O. Salant, Phys. Rev. Letters 27 (1971) 1745

[19] V.S. Murzin and L.I. Sarycheva, Cosmic rays and their interactions, NASA Technical Translation TTF-5'94 (1970);
E. Lohrman et al., Phys. Rev. 122 (1961) 672;
N.L. Grigorov et al., Proc. Int. Conf. on Cosmic Rays, Moscow Vol. 1 (1960) 140 ;
M. Koshiba et al., Proc. Int. Conf. on Cosmic Rays, Jaipur, Vol. 5 (1964) 293

TABLE 1

Values of the average charged multiplicity in pp collisions

$E_{c.m.}$ (GeV)	$<n_{ch}>$	Ref.	Notes
3.08	2.54 ± 0.03	[8]	Bubble chamber data
3.50	2.71 ± 0.01	[9]	
4.54	3.22 ± 0.06	[10]	
5.10	3.58 ± 0.03	[11]	
5.97	3.93 ± 0.02	[11]	
6.12	4.02 ± 0.02	[12]	
6.43	4.21 ± 0.02	[11]	
6.84	4.31 ± 0.06	[13]	
6.85	4.41 ± 0.02	[11]	
7.43	4.58 ± 0.02	[11]	
7.44	4.42 ± 0.03	[14]	
9.7	5.47 ± 0.12	[15]	Mirabelle, Serpukhov
11.4	5.81 ± 0.13		
11.4	6.59 ± 0.24	[16]	Emulsion, Serpukhov
14.9	5.5 ± 0.3	[17]	Echo Lake, cosmic rays
19.7	6.0 ± 0.2		
23.5	6.4 ± 0.3		
28.4	6.5 ± 0.4		
36.1	7.1 ± 0.6		
30.2	9.3 ± 1.4	[6,7]	γ-production, ISR
44.7	10.5 ± 1.6		
52.7	10.9 ± 1.7		
21.3	7.3 ± 1.1	This Work	Charged-particle production, ISR
30.4	9.7 ± 1.5		
44.3	11.2 ± 1.7		
52.2	12.7 ± 1.9		
143.0	18.8 ± 3.0	[18]	Cosmic rays
21.7	8.8 ± 1.9	[19]	Cosmic rays
23.7	9.0 ± 1.0		
49.4	11.0 ± 2.0		
151.9	16.0 ± 3.0		

FIGURE CAPTIONS

Fig. 1 The differential cross sections $(1/2\pi)\, d\sigma/dy$ (mb) plotted against $y_{projectile}$.

Fig. 2 Plot of the average charged multiplicity in pp collisions as a function of the c.m. energy (GeV). These data are all contained in table 1. The lower curve is the ln fit and the upper curve is the power fit to the bubble chamber and ISR data.

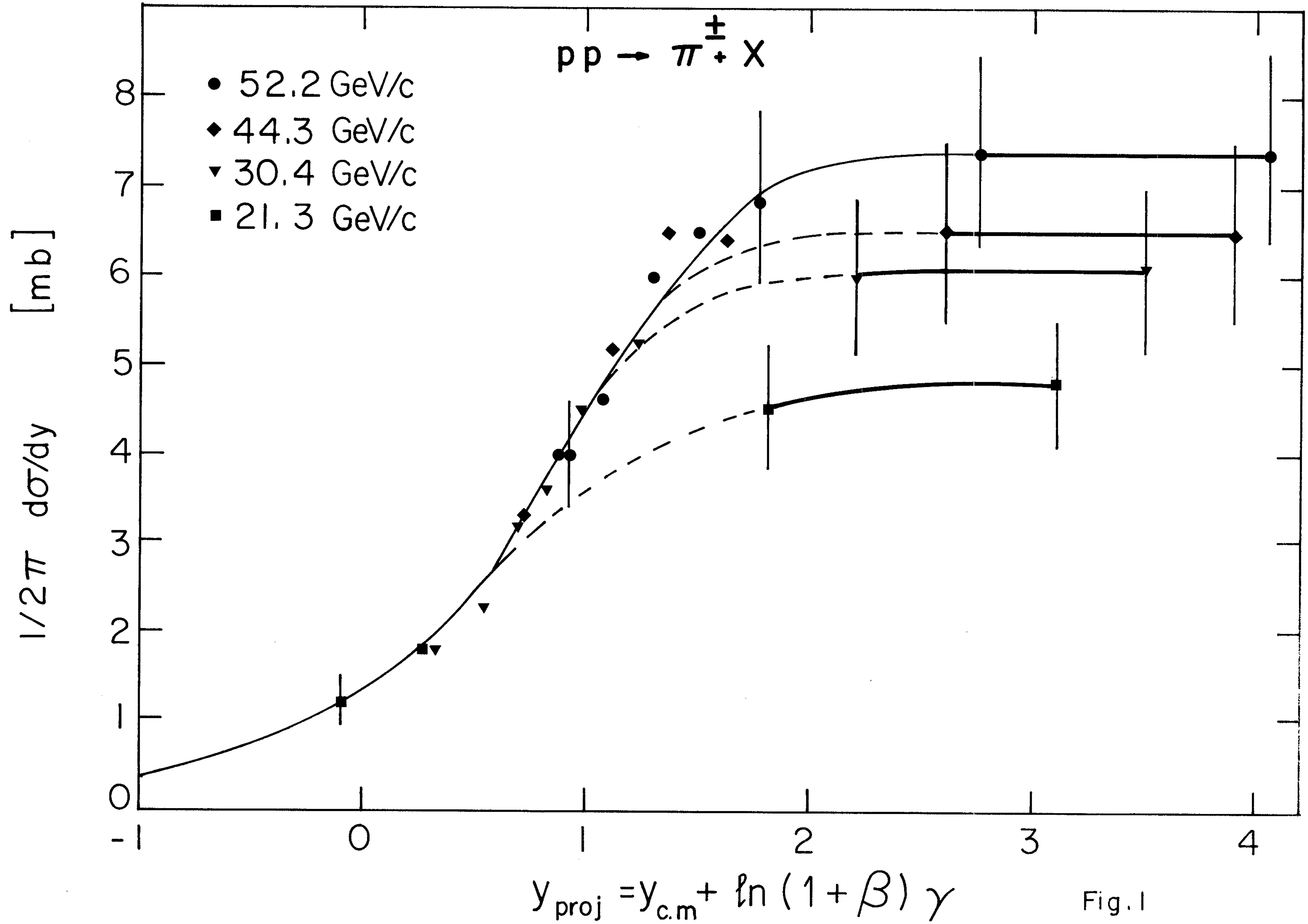
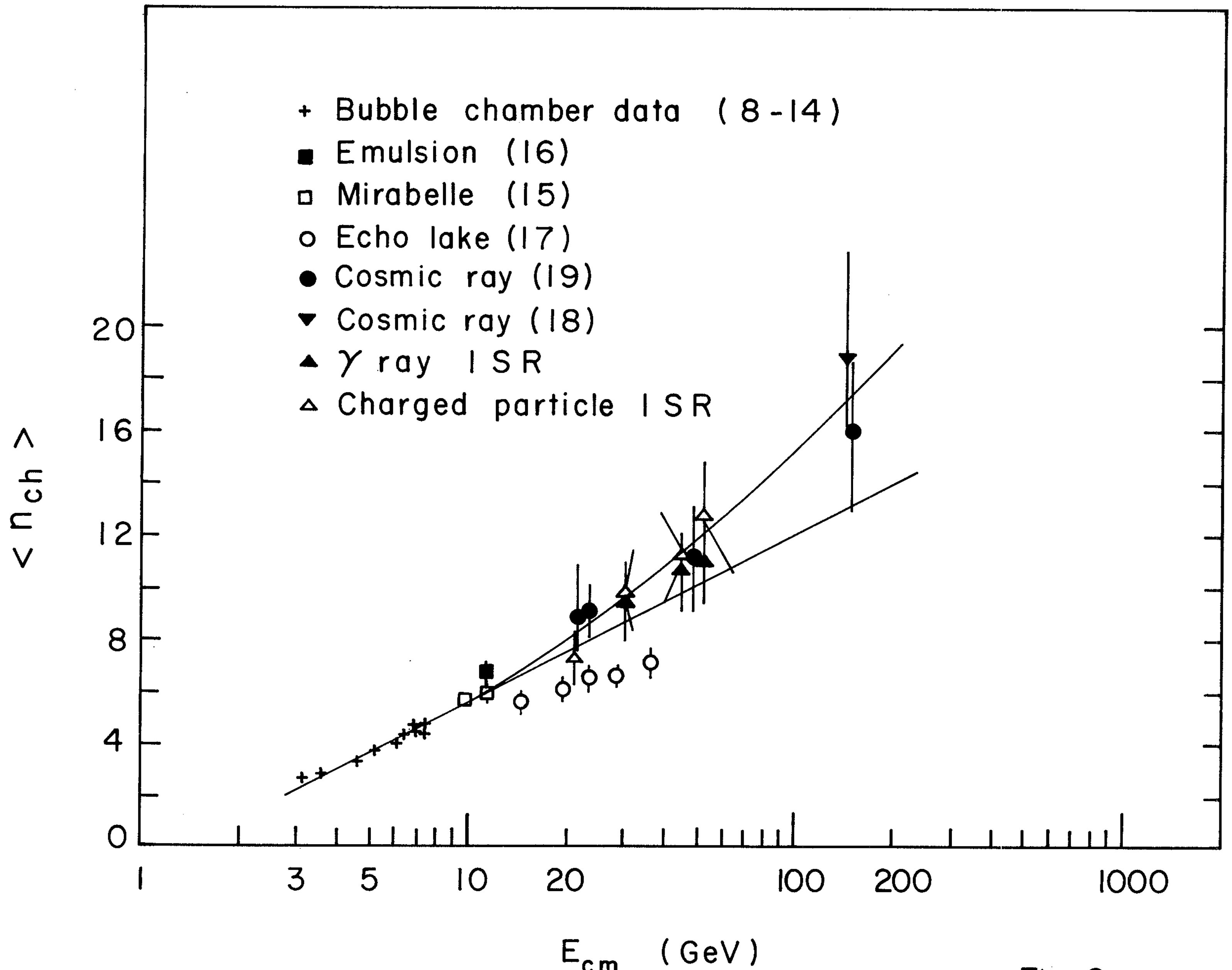

pp → π± X
• 52.2 GeV/c
◆ 44.3 GeV/c
▼ 30.4 GeV/c
■ 21.3 GeV/c
1/2π dσ/dy [mb]
y_proj = y_c.m + ln (1 + β) γ
0 1 2 3 4 5 6 7 8
-1 0 1 2 3 4

Fig. 1



+ Bubble chamber data (8-14)
■ Emulsion (16)
□ Mirabelle (15)
○ Echo lake (17)
● Cosmic ray (19)
▼ Cosmic ray (18)
▲ γ ray ISR
△ Charged particle ISR
< n_ch >
0
4
8
12
16
20
1
3
5
10
20
100
200
1000
E_cm (GeV)

Fig. 2