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A.Mihul, T.Angelescu

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Recently some theoretical papers have pointed out the interest of using charge transfer in analysing high energy inclusive processes. So, Chou and Yang have used the fragmentation picture [1] and Quigg and Thomas [2] the multiperipheral model, to predict the behaviour of the transfer of the charge between the forward (projectile) and backward (target) hemisphere; some other approaches have also been used [3,4]. All these model considerations are affected by the very crude assumptions made in each case and therefore their predictions are only qualitatively valid. Anyway, we found interesting to gather a more complete set of experimental information about the charge transfer and compare it with the existing theoretical predictions.

A difficulty which appears when comparing the model predictions with the experimental data is the fact that all models deal with proton-proton interaction only, that is a completely symmetrical system in the initial stage of the reaction. The behaviour of asymmetrical systems is avoided in all theoretical considerations.

The comparison of the model predictions with experiment is also complicated by the scarcity of the experimental data on ΔQ most of them being given only on plots. So far, apart these data we tried to use also some published inclusive distributions to compute the charge transfer values. The biases introduced by the used procedure do not affect the general conclusions of this discussion. The possible biases have been taken into account in computing the corresponding errors.

The charge transfer for each interaction has been defined by:

$$\Delta Q = \sum_f Q_f - Q_i \,,$$

where Q_f is the charge of final state particles in the forward (projectile) hemisphere and Q_i is the charge of the incident particle. The charge transfer value averaged over all kinds of transfers and all multiplicities can be computed either from the charge transfer distributions:

$$\langle\langle \Delta Q \rangle\rangle = \frac{\sum_j \Delta Q_j \, \sigma_j}{\sum_j \sigma_j} \,,$$

where σ_j is the cross section for a given charge transfer ΔQ_j or from the charge distribution in final state on one kinematical variable (for example the longitudinal momentum $p_{\parallel}$)

$$\langle\langle \Delta Q \rangle\rangle = \frac{1}{\sigma_{tot}^{in}} \sum_f \int_{p_{\parallel}=0}^{p_{\parallel}=p_{\parallel}^{max}} Q_f \frac{d\sigma_f}{dp_{\parallel}} dp_{\parallel} - Q_i \,.$$

Both methods have been used in order to compile most of the available data.

The values of the averaged charge transfer for different interactions are plotted in fig. 1. When interpreting these data we should remember that, appart the quoted errors, there are systematical errors due to experimental biases and especially to particle identification. Anyway from fig. 1 it is possible to draw some conclusions for the interactions in the 1÷500 GeV/c beam momentum range.

In fact, while all models predict asymptotically a zero value for the average charge transfer, the experimental value is compatible with zero only for pp interactions. For all the others it is different from zero outside the errors. This fact indicates either that the asymptotics has not yet been reached for all interactions, but pp ones, or that the model predictions are not valid for asymmetrical systems.

The average charge transfer is negative for $\pi^+ p$ interactions while positive for all other available interactions ($\pi^- p$, $K^- p$, γp, $\bar{p}p$). This can be a consequence of the trend to the conservation of the charge in each hemi-

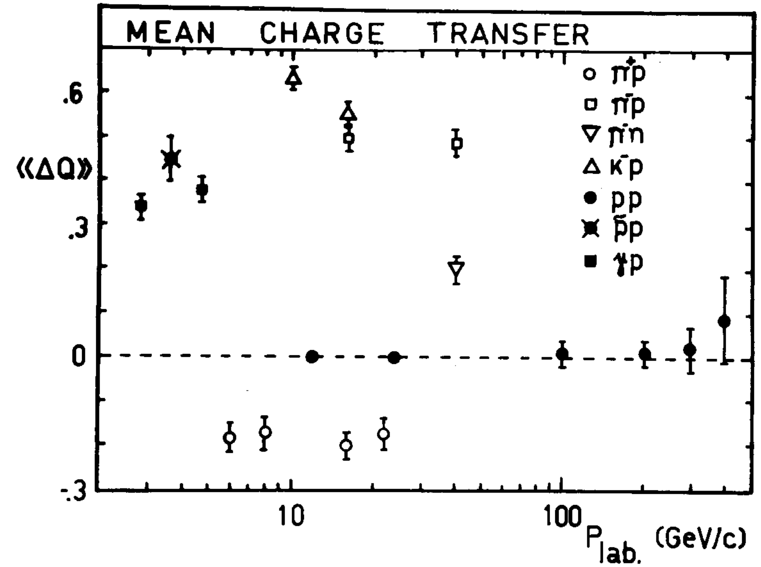

Fig. 1. Average charge transfer as function of the primary momentum. ○ $\pi^+ p$ *interactions (6 GeV/c computed from the distributions given in* /13/ *; 8 GeV/c after the* dQ/dx *distribution from* /11/ *and plot from* /16/ *; 16 GeV/c computed on the basis of* dQ/dx *distribution given in* /12/ *and from* ΔQ *plot from* /16/*; 22 GeV/c computed from inclusive distributions given in* /13/); □ $\pi^- p$ *interaction (16 GeV/c computed from* dQ/dx *distribution from* /11/ *and* ΔQ *plot from* /16/ *; 40 GeV/c values quoted in* /14/); ▽ $\pi^- n$ *interaction (40 GeV/c values quoted in* /19/; △ $K^- p$ *interaction (10 and 16 GeV/c values quoted in* /5/); ● pp *interaction (12 and 24 GeV/c readed on plots given in* /6/ *; 102 and 400 GeV/c readed on plots given in* /10/*; 205 GeV/c value quoted in* /18/ *; 300 GeV/c private communication from Dr. E.Malamud);* ✱ $\bar{p}p$ *interaction (3.6 GeV/c computed from experimental data distribution supplied by Dr. T.P.Yiou for 4 and 6 prong inelastic and annihilations; for* $\bar{p}p$ *at rest a value* $\langle\langle \Delta Q \rangle\rangle = .9 \pm .1$ *was computed from experimental distributions given by Dr. J.Gay for 2;4 prong);* ■ γp *interaction (2.8 and 4.7 GeV/c computed using the inclusive distributions given in* /9/ *). The line at* $\langle\langle \Delta Q \rangle\rangle = 0$ *is the asymptotical prediction of all models.*

sphere or, with other words, of the inertia of the charge.

In this case we could predict for the interactions on protons or neutrons a positive average charge transfer value for negative or neutral incident particles, and a negative or zero value when the incident particles are positive.

The fact that the values $\langle\langle \Delta Q \rangle\rangle$ for $\pi^+ p$ are negative but of the same magnitude as for $\pi^- n$ can be an indication of a symmetry in the plot in respect with the T_3 conjugation, but to draw such a conclusion more experimental data, especially on $\pi^+ n$ and $K^+ n$ interactions, would be necessary.

Another parameter which describes charge transfer is the squared dispersion defined by the relation:

$$D^2 = \langle\langle \Delta Q \rangle\rangle^2 - \langle\langle \Delta Q^2 \rangle\rangle .$$

The prediction for the behaviour of the squared dispersion of the charge transfer distribution when increasing energy are completely different in the Chou and Yang and Quigg and Thomas approaches. While Quigg and Thomas in the frame of multiperipheral picture, predict a constant value for D^2 at asymptotic energies, Chou and Yang give for the fragmentation model the surprising prediction of a squared dispersion raising with energy like p_{cms}. It seems that this prediction for D^2 is very sensible to the approximations made by the authors and this behaviour is not specific for the fragmentation model. The model of independent produced particles gives also the strange result of a rise of D^2 proportional to the average number of particles produced, that is like $\ln s$ [3]. If in this model a partial clusterisation is introduced the result tends to the Quigg and Thomas prediction.

We present in fig. 2 the experimental data on D^2 for $\pi^{\pm} p$, $\pi^- n$, $K^- p$ and pp interactions for different beam momenta in the range 8 to 400 GeV/c. These values vary slowly from $D^2 \simeq .7$ at about 10 GeV/c to approximately $D^2 \simeq 1$ at 400 GeV/c. On the same figure the predictions of the above discussed three models are drawn, namely:

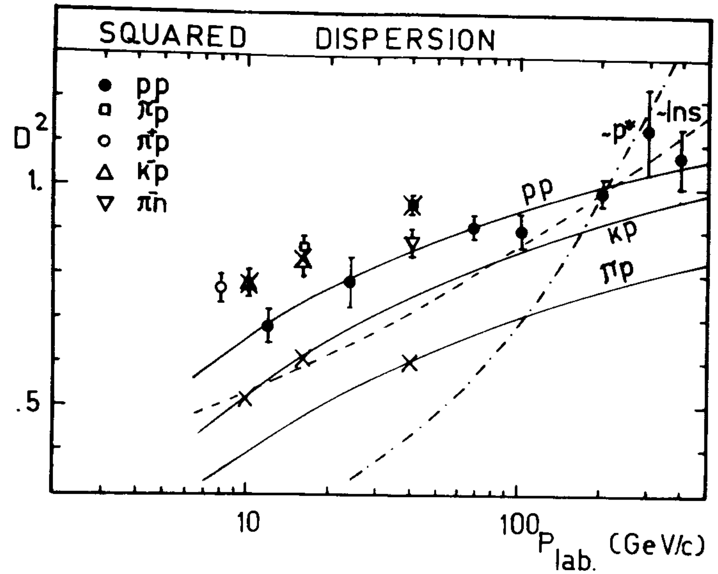

Fig. 2. Charge transfer squared dispersion as function of the incident particle momentum. ○ $\pi^+ p$ *interaction (8 and 16 GeV/c computed after values for* ΔQ *plotted in* [16]*);* □ $\pi^- p$ *interaction (16 GeV/c calculated after* ΔQ *values plotted in* [16]*; 40 GeV/c values quoted in* [11]*);* ▽ $\pi^- n$ *interaction (40 GeV/c value quoted in* [19]*);* △ $K^- p$ *interaction (10 and 16 GeV/c value quoted in* [5]*);* • pp *interaction (12 and 24 GeV/c values quoted in* [3]*; 69 GeV/c value quoted in* [20]*; 102 and 400 GeV/c computed after the* ΔQ *plot given in* [10]*; 300 GeV/c private communication from Dr. E.Malamud for events with* $n_{ch} \geq 6$ *). The dotted line is the dependence like* p_{cms}*, the dash-dotted line is a* $\ln s$ *dependence (both normalized to the experimental value at 200 GeV/c). The full lines are the dependence computed using the formula given in* [2].

1) Chou and Yang [1] $D^2 \simeq p_{cms.}$ dash-dotted line,
2) Fialkowski [3] $D^2 \simeq \langle n \rangle \simeq \ln s$ dashed line,
3) Quigg and Thomas [2] $D^2 = \frac{4}{3} \frac{\Delta}{Y_{max.}} \langle N \rangle$ full line.

The curves 1 and 2 have been normalized to the point of 200 GeV/c in pp interactions. The curves 3 have been computed for pp, Kp and πp interactions using $\Delta = 1.1$, the average number of clusters $N = \frac{1}{2}(a + b \ln s)$ with $a = -2.9$ $b = 1.79$ /17/ and $Y_{max.}$ the maximum rapidity region available for the incident particles.

From the first sight it is clear that the experimental data for pp interactions tend to a limiting value of about 1 in agreement with the multiperipheral model and in obvious disagreement with a $p_{cms.}$ or $\ln s$ rule. Another characteristic is that all dispersion values corresponding to interactions of pions or kaons on protons are greater than those corresponding to pp interactions at the same incident momentum, and that it is not possible to describe at the same time all the experimental points using the Quigg and Thomas formula with a single value for the parameter Δ. In order to discuss this point we wrote the Quigg and Thomas formula for the production of N clusters:

$$D^2(N) = \frac{4}{3}\,\frac{\Delta}{Y}N\,.$$

For a general model the mobility parameter Δ should be the same in all interactions taking into account the fact that it is a characteristic of the produced cluster and not of the primary particles. The value Y in this formula is in fact the rapidity length corresponding to the available phase-space for the production of N clusters and must be written Y(N). So, when we average over the number of clusters we must write:

$$D^2 = \frac{4}{3}\,\frac{\Delta}{\langle Y(N)\rangle}\langle N\rangle\,.$$

The computation of $\langle Y(N)\rangle$ is difficult because it is a function of the mass of the cluster which is unknown. We approximate the ratio $Y_{max}/Y(N)$ for the production of one and two clusters with the mass equal to $3m_\pi$, for πp interactions at 40 GeV/c, by a rough computation and found 1.28 and 1.33 respectively. In the asymptotic case $(s \to \infty)$ this ratio should tend to 1. The ratio will also be 1 for $N = 0$.

For a better approach we tried to find the value of this ratio from the experimental data on D^2 as a function of the number of charged particles n_{ch} produced in the interaction. Fig. 3 gives the distribution of the value:

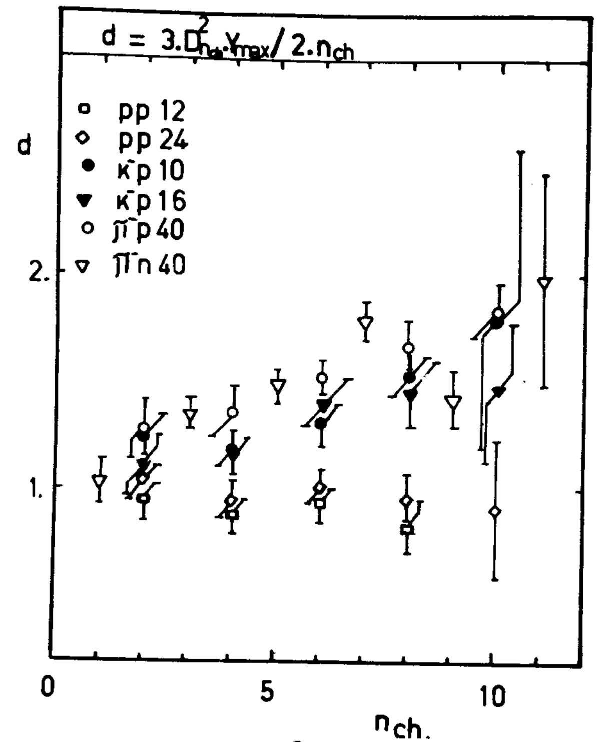

Fig. 3. The value $d = (3/2)D^2_{n_{ch}}Y_{max}/n_{ch}$ *as function of the charge multiplicity.* pp *12 GeV/c* □ *, 24 GeV/c* ◇ *computed from data given in* /6/ *;* K^-p *10 GeV/c* ● *, 16 GeV/c* ▼*, readed from graphs from* /5/ *;* π^-p *40 GeV/c* ○ *from* /14/*;* π^-n *40 GeV/c* ▽ *from* /19/.

$$d(n_{ch}) = \frac{3}{2}\,\frac{D^2_{n_{ch}}\,Y_{max}}{n_{ch}}\,.$$

which should be in the Quigg and Thomas model frame equal to:

$$d(n_{ch}) = \Delta\,\frac{Y_{max.}}{Y(N)}\,.$$

The value d will tend to Δ when $Y_{max}/Y(N)$ will be 1, that is, either at $s \to \infty$, or when $N = 0$. From Fig. 3 we see that for $\pi^- n$, $\pi^- p$, $K^- p$ reactions d varies much with n_{ch} while for pp interactions has a very small variation. The lack of variation for pp is to be expected as, for Y_{max} in the pp interaction we took the value corresponding to the two incident protons while the value for produced pions is bigger.

To find a rough value for d we averaged the values of $d(n_{ch})$ for $n_{ch}=4;6;8$ and 10 with an equal weight. Using this average we corrected the values of D^2 given by the model for $\pi^- p$ at 40 GeV/c and $K^- p$ at 10 and 16 GeV/c. In fig. 2 these new theoretical values and their corresponding old ones are indicated by a "x". The corrected values are in good agreement with the experimental ones.

The confruntation of the available experimental data on charge transfer with theoretical models led us to the following conclusions:

- the experimental values of the average charge transfer in interactions with asymmetrical particles cannot be described by the existing models;
- the dispersions D^2 are well described by the multiperipheral model for all incident particles only if taking into account the dependence of Y on multiplicity;
- in the Quigg and Thomas model frame we can conclude that the existing experimental data (fig. 3) do not contradict the existence of one value of the mobility parameter of about 1.1 common to all kinds of interactions.

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