СООБЩЕНИЯ
ОБЪЕДИНЕННОГО
ИНСТИТУТА
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ

Дубна

E1 - 6745

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AVERAGE QUANTUM NUMBER PER PARTICLE. WHAT ARE THEY GOOD FOR?

ЛАБОРАТОРИЯ ВЫЧИСЛИТЕЛЬНОЙ ТЕХНИКИ
И АВТОМАТИЗАЦИИ

1972

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In the analysis of elementary particle interactions at high energies, correlations between kinematical parameters and cross-sections are always considered, but the study of the correlations between kinematical parameters and quantum numbers is almost always absent.

Some time ago (1971 Helsinki Conference) Van Hove suggested to investigate, in multiple production, the correlations between the electric charge of secondary particles and some kinematical variables like c.m. longitudinal momentum (P_L), longitudinal rapidity (y) or others /1/. The distribution proposed was that of the total electric charge of the outgoing particles in the corresponding kinematical interval. At the Oxford Conference (1972) D.R.O.Morrison presented some charge distributions for the 8 GeV/c and 16 GeV/c π^+p and 16 GeV/c π^-p interactions using the single particle distributions $\frac{d\sigma_c}{dx}$ in inclusive reactions (a + b $\longrightarrow$ c + anything) /2/. The charge distribution was given by:

$$\frac{dQ}{dx} = \frac{1}{\sigma_{in}} \left[\frac{d\sigma_p}{dx} + \frac{d\sigma_{\pi^+}}{dx} - \frac{d\sigma_{\pi^-}}{dx} \right] = \frac{1}{\sigma_{in}} \sum_c Q_c \frac{d\sigma_c}{dx} ,$$

where $x = (P_L / P_{L.max})_{c.m.}$ and Q_c is the charge of particle c.
The distribution was normalized to the initial charge value Q_{in} :

$$\int_{-1}^{+1} \frac{dQ}{dx} dx = Q_{in}$$

One of the purposes of this analysis has been to try to separate the "incident particle effect". Some effect of the leading properties was seen as expected near x = 1 and x = -1. but, at the same time, the behaviour near x = 0. was unexpected. (fig.1.).

We tried to extend this kind of analysis in the following way:

1. By introducing an average value of charge per particle $(\langle Q \rangle_n)$. The average is got by dividing the value of the algebraical sum of charges of the produced particles

in the kinematical interval by the number of particles produced in the same interval irrespective of the fact that they are neutral or charged. The average charge per particle distribution is then defined by:

$$\langle Q(k)\rangle_n = \frac{\sum_c Q_c \frac{d\sigma_c}{dk}}{\sum_c \frac{d\sigma_c}{dk}} = \frac{\frac{dQ}{dk}}{\frac{dn}{dk}},$$

where k is the kinematical variable and $\frac{dn}{dk}$ is the total multiplicity distribution. Summations extend over all kinds of secondaries (neutral or charged).

If there is no correlation between the produced charge and the kinematical variable k, the corresponding average charge distribution should be constant:

$$\langle Q(k)\rangle_n = \frac{Q_{in}}{\langle n\rangle},$$

where $\langle n\rangle$ is the total average multiplicity.

Correlations can be artificially introduced by using incomplete samples. This fact should be carefully examined when experimental distributions do not include all particles (all charged partners).

2. By extending the definition of the average charge to other quantum numbers. In this way we can take into account correlations between different charges (electric Q, baryonic B, strange S, ...) and some appropriate kinematical variable (P_L, x, y...) or correlations between different quantum numbers.

It is interesting to point out the fact that the average quantum number (AQN) connects quantum numbers and multiplicities.

The quantities defined above permit the description of the final state in terms of densities of different quantum numbers, some aspects of the interaction being studied by measuring the correlations between AQN and appropriate kinematical parameters. This is a new field of correlations to be studied.

In order to give a more precise idea about the way of using such quantities we tried to sketch an analysis of the leading effect looking at different AQN distributions.

Unfortunately, the published data do not give complete information about single particle spectra and therefore we can indicate only some rough results.

We chose the kinematical variable x as being more convenient for the study of leading properties. Using single particle distributions in inclusive reactions we plotted $\langle B(x)\rangle_n$ (fig.2), $\langle Q(x)\rangle_n$ (fig.3), $\langle S(x)\rangle_n$ (fig.4) for different πp, pp and Kp reactions, /2,4,5/

The values were calculated on the basis of the published plots with the following hypotheses:

- As there is little information about the π^0 production, their spectrum has been taken like that of the non-leading charged pion /3/. A change of this spectrum does not modify the main features of the AQN distributions. As an example, we compare in fig.5 the

$<B(x)>_n$ and $<Q(x)>_n$ distribution in $\pi^+ p$ at 6 GeV/c and 22 GeV/c /4/ computed using a π^o spectrum equal to the π^- one, with the same distribution computed with the hypothesis that π^o spectrum is the average of both π^+ and π^- distributions.

The spectrum of neutrons (antineutrons) was taken as 0.6 times the spectrum of protons (antiprotons). This approximation is based upon the indication given by D.R.O.Morrison in his report at the Oxford Conference /2/: "In pp reactions... it is found that there are about 1.2 protons and 0.8 neutrons...". A change of this coefficient between 0.5 and 1 does not affect strongly the AQN distributions.

A more important effect would have a change of the shape of the neutron spectrum but, we found no information about the shape and therefore we cannot answer this question.

- Some of the $\frac{d\sigma_c}{dx}$ distributions were computed from $\frac{E d\sigma_c}{dx}$ plots given by the authors. In doing these computations we used for all secondaries the same average transverse momentum $<p_T> = 0.35$ GeV/c /2/ .

- Strange particle production was neglected when no information about their spectrum was available. We expect no sensible change of the results by including strange particle spectra as their cross-sections are small, and the distributions are similar to the distributions of particles already taken into account.

- For proton-proton interactions only the data at fixed transverse momentum $p_T=$ 0.4 GeV/c were used.

- Elastic events were included only in proton-proton interactions (counter experiments).

Average Baryon Quantum Number Distribution

For the interval $-1. < x < 0.$ the $<B(x)>_n$ distribution (fig.2) shows the well known fact that the secondary baryons have a tendency to follow the direction of the incident baryon. The unexpected fact is the similitude of their shape over a wide range of energies and interactions (from $\pi^- p$ at 6 GeV/c to pp at 1500 GeV/c). Errors in reading plots, statistical ones and biases due to the way in which identification has been carried on in each laboratory, are high enough to explain the differences. We can speak here of a kind of scaling of the baryon AQN over this range of energies.

For the interval $0. < x < 1.$ the distribution of $<B(x)>_n$ changes from interaction to interaction. All data for πp interactions were obtained in bubble chamber experiments and for this x interval a lot of difficulties arise in particle identification. (a 14 ÷ 30% of misidentification is claimed by the authors at 6 and 22 GeV/c /4/). Our feeling is that these difficulties are at the origin of most of the differences seen for $x > 0$. The distribution for pp interactions we used was folded on $x=0.$; Therefore we made distributions only up to $x = 0$.

Average Electric Charge Distribution

As both initial particles are charged we expect a more or less symmetrical distribution. When both initial particles have the same charge there is a dip near x = 0. When the charge of incident particles is opposite the distribution changes the sign near x = 0. The values near x = -1. or x = +1. depend very much on the neutron and π^{o} spectra. The general shape of all these distributions shows the tendency of the electric charge to follow the direction of motion of the initial charge.

Average Strangeness Distribution

This distribution for Kp interactions shows also the tendency of strangeness to move along the direction of the incident strange particle, but the available data are very poor.

In conclusion, we can say that all the AQN distributions show a kind of "inertia" of the incident particle quantum numbers. It seems that in the $\langle B(x)\rangle_{n}$ distribution a scaling effect occurs even at accelerator energies.

These conclusions are only very preliminary. They were quoted only in order to excite the interest of various groups which have the possibility to try a complete analysis on their own material. A study of $\tilde{p}p$ and γp interactions would be also very interesting.

Acknowledgements

The authors want to acknowledge in this way Acad. N.N.Bogolubov for interesting comments and discussions. It is also a pleasure to thank our colleagues S.Berceanu, V.Cautis, C.Georghe and Dr.Eleonora Mihul for many valuable comments, observations and help in preparing the material.

References

1. L.Van Hove. Longitudinal Phase Space Analysis and Related Questions. Lecture at the Colloquium on Multiparticle Dynamics, Helsinki, 25-28, May, 1971, TH 1365 - CERN.

2. Douglas R.O. Morrison. Review of Many-Body Interactions at High Energy. Review talk at the Fourth International Conference on High Energy Collisions (Stony Brook series), Oxford, April, 1972, CERN (D.PH.N.) Phys; 72-19.
3. G.R.Charlton. Charged Particle Multiplicity Distribution from 200 GeV pp Interactions P.R.L., 29, 515 (1972), ANL-HEP-7217 (1972), P.L. 40B, 378 (1972).
4. D.J.Crennel. Study of Inclusive Reactions of $\pi^+ p \to x$ + anything $(x = \pi^+, \pi^-, K^\circ_s)$ at 6 and 22 GeV/c. PRL, 28, 643 (1972).
5. A.B.C.L.V.Collaboration. Lambda Production in 10 GeV/c $K^- p$ Interactions N.P., B5, 606-618 (1968).

Received by Publishing Department
on September 28,1972

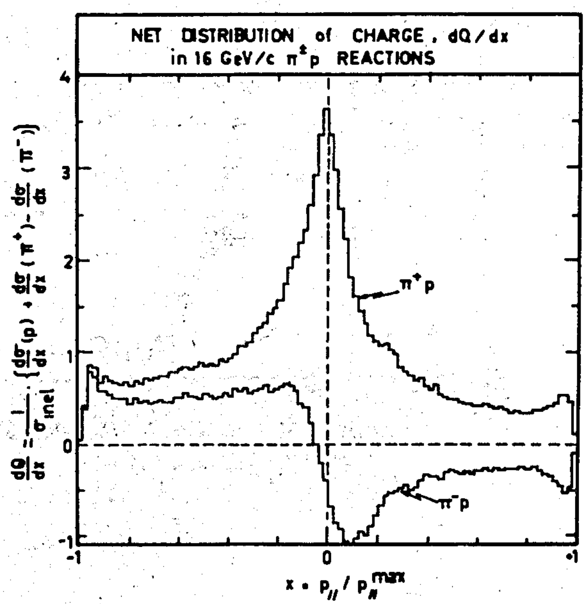


Fig.1

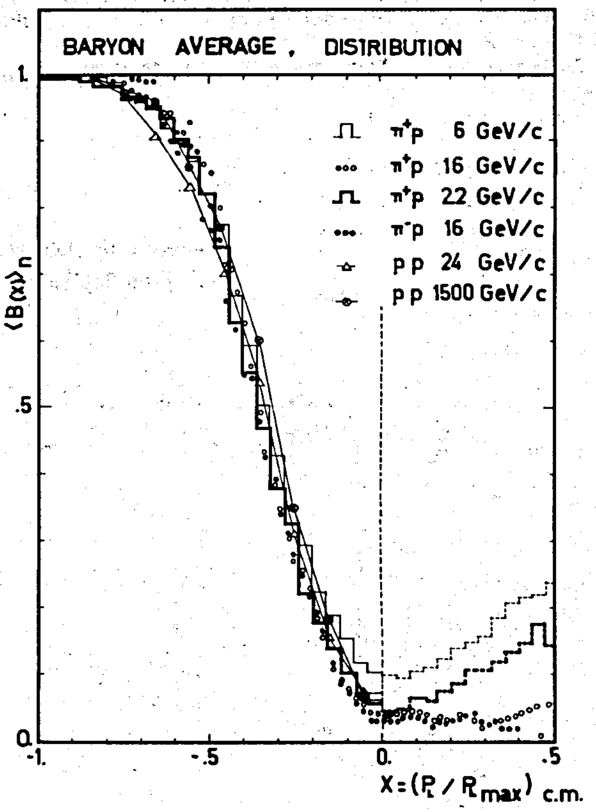

BARYON AVERAGE , DISTRIBUTION
1.
.5
0.
-1.
-.5
0.
.5
⟨B(x)⟩n
X=(PL / PLmax) c.m.
π+p 6 GeV/c
π+p 16 GeV/c
π+p 22 GeV/c
π-p 16 GeV/c
p p 24 GeV/c
p p 1500 GeV/c

Fig.2

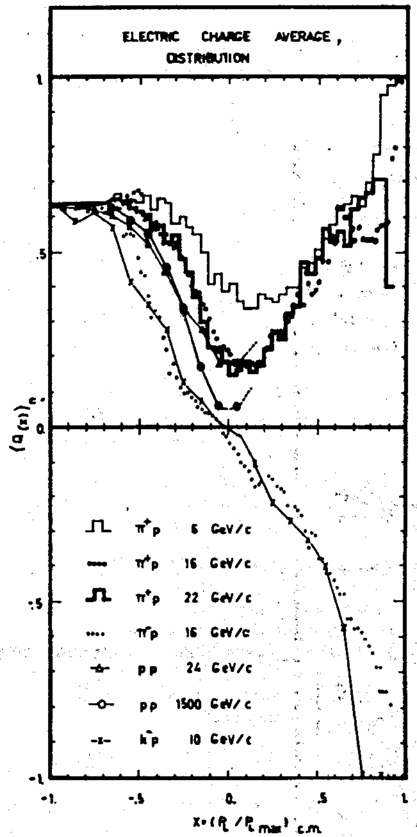

ELECTRIC CHARGE AVERAGE , DISTRIBUTION
$\langle q_{(x)} \rangle_c$
$\pi^+ p$ 6 GeV/c
$\pi^+ p$ 16 GeV/c
$\pi^+ p$ 22 GeV/c
$\pi^- p$ 16 GeV/c
p p 24 GeV/c
p p 1500 GeV/c
$k^- p$ 10 GeV/c
$x = (P_L / P_{L\,max})_{c.m.}$

Fig.3

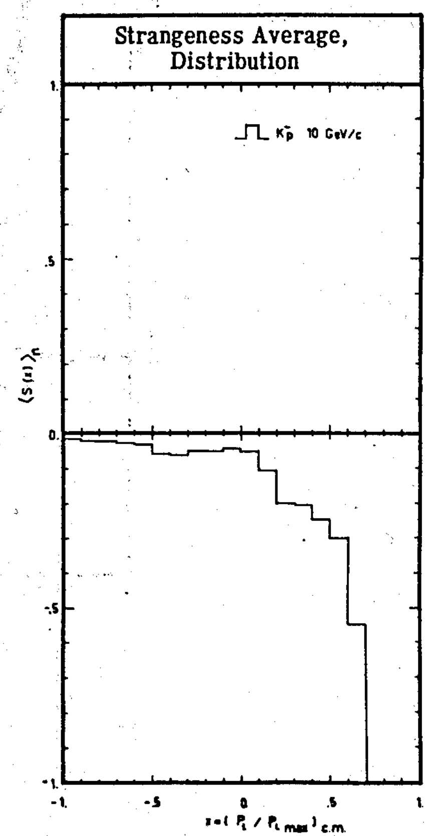
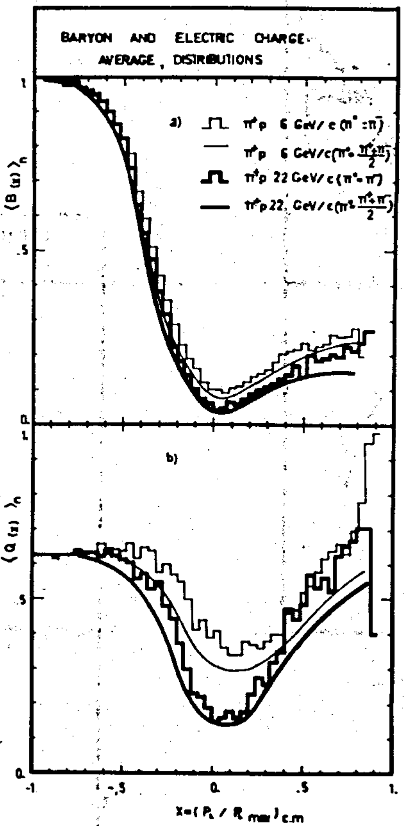

Strangeness Average, Distribution
$K^- p$ 10 GeV/c
$\langle S_{(x)} \rangle_n$
$x = (P_L / P_{L\,max})_{c.m.}$

Fig.4



BARYON AND ELECTRIC CHARGE
AVERAGE DISTRIBUTIONS
a)
b)
.5
0.
1.
-1
-.5
X=(P_L / P_max) c.m

Fig.5