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OBSERVATION OF INCREASING CHARGED MULTIPLICITY AS A FUNCTION OF TRANSVERSE
MOMENTUM IN 28.5 GeV/c pp INTERACTIONS (P 454)

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B.N.L.

Systematic studies of multiparticle final states in PP collisions around 30 GeV/c have been carried out in bubble chambers [1]. They have covered extensively the large cross-section peripheral interactions but have had no access to rare events, e.g. large momentum transfer collisions. They have suffered from technical shortcomings in identifying the final state protons. The simplest features of the data, i.e. single particle inclusive distributions and two-body correlations can be understood in terms of the production and decay characteristics of the excited nucleon system (nova model) [2]. The data appear insensitive to detailed features of the dynamics. A study of collisions imparting higher transverse momentum to the incident proton may be more sensitive to the dynamics since in that case one is probing a more central region of the proton. With this motivation we have initiated a study of such central collisions with a novel instrument, the Multiparticle Argo Spectrometer System [3] (MASS), at the AGS.

We report here the dependence of the mean charged multiplicity \bar{N}_{CH} on the transverse momentum p_{\perp} of the forward proton in the reaction



for five intervals of missing mass MM. To measure this dependence, we have used two of the three spectrometers constituting the ensemble of MASS. The High Momentum Spectrometer (HMS) was used to trigger upon, identify, and momentum analyze the forward proton. In three floor positions, scattering angles in the laboratory frame between 14 mrad and 100 mrad and momenta between 10 GeV/c and 28.5 GeV/c were covered. The angular and momentum resolutions were $\pm .2$ mrad and $\pm .3$ % at 20 GeV/c respectively and the solid angle acceptance was 33 mr horizontally by 10 mr vertically. The vertex spectrometer [4] (VS) was used to measure the charged multiplicity. It consisted of nine digitized cylindrical wire spark chambers operating in a ten kilogauss magnetic field and surrounding an

eight inch long hydrogen target. The chambers subtended a solid angle such that 89 % of all charged particles were detected. Track identification in the VS was performed with the automatic track recognition code Pitrack [5]. A subset of the data was scanned by physicists to determine the biases. Approximately 6 % of all tracks were not recognized by Pitrack.

The charged multiplicity distribution for three intervals of p_{\perp} in the MM interval 2.0 to 3.0 GeV are displayed in Fig. 1. Losses of charged particles have

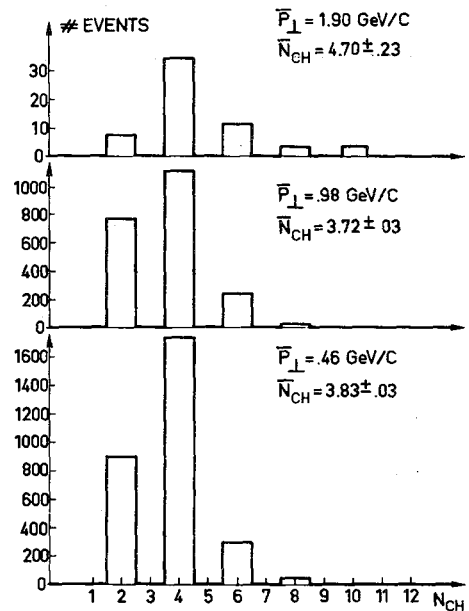


Fig. 1.- The corrected charged multiplicity distributions in the MM interval 2.0 - 3.0 GeV for three values of transverse momentum to the forward proton.

been calculated using charge conservation on an event by event basis. The losses of two particles of opposite charge were determined from the known losses of two particles of equal charge.

It is apparent from the data that the multiplicity distribution for high p_{\perp} differs from the other two

distributions resulting in a higher mean charged multiplicity. Since the average missing mass value differed by a small amount for different p_{\perp} intervals, a small correction δN_{MM} has been applied (Table I). The correction was based on the observation of a linear relationship between \bar{N}_{CH} and MM for fixed p_{\perp} with a slope of $.75 \text{ GeV}^{-1}$.

In Fig. 2 we show the variation of the mean charged multiplicity \bar{N}_{CH} with p_{\perp} for five intervals of MM. While the data show little variation of \bar{N}_{CH} with p_{\perp} up to 1 GeV/c, a rapid rise of \bar{N}_{CH} can be seen for values of $p_{\perp} > 1 \text{ GeV/c}$. It is possible that the lowest MM interval does not display this behavior

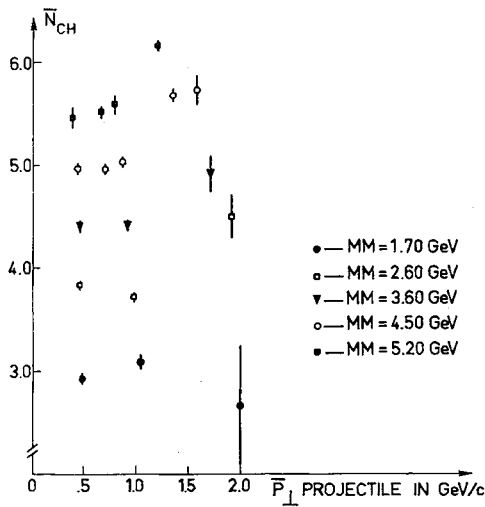


Fig. 2.- The variation of the average charged multiplicity \bar{N}_{CH} with p_{\perp} for five intervals of missing mass MM.

because of insufficient available energy. The errors in Fig. 2 do not include an overall systematic error. We have investigated the systematic error on \bar{N}_{CH} by comparing subsets of our data at low p_{\perp} with bubble chamber information. Our \bar{N}_{CH} is systematically higher by $\sim 5\%$ compared to the mean charged multiplicity in bubble chamber data [6]. We attribute this difference to undetected secondary interactions in the hydrogen target, gamma conversion close to the vertex etc. The data have not been corrected for this systematic error.

We have also looked at the corrections as a function of p_{\perp} . Charge corrections are the same within errors for all intervals of p_{\perp} . In other words, the uncorrected data show the same behavior of \bar{N}_{CH} versus p_{\perp} as the corrected ones but the \bar{N}_{CH} values are lower by about 17% due to solid angle losses

reconstruction inefficiencies. For detailed information on each data point, see Table I.

Missing Mass in GeV	\bar{p}_{\perp}	δN_{MM}	\bar{N}_0	δN_1	δN_2	\bar{N}_{CH}
$1.3 \leq MM < 2.0$ $\overline{MM} = 1.7$	0.49(0.14)	0.03	2.47	0.39	0.07	2.93 ± 0.05
	1.05(0.12)	0.02	2.62	0.32	0.07	3.01 ± 0.05
	1.98(0.10)	-0.01	2.66	--	--	2.66 ± 0.61
$2.0 \leq MM < 3.0$ $\overline{MM} = 2.6$	0.46(0.15)	0.04	3.28	0.45	0.10	3.83 ± 0.05
	0.98(0.14)	0.01	3.20	0.42	0.10	3.72 ± 0.03
	1.90(0.15)	-0.02	3.83	0.47	0.22	4.50 ± 0.21
$3.0 \leq MM < 4.0$ $\overline{MM} = 3.6$	0.46(0.15)	0.06	3.74	0.56	0.11	4.41 ± 0.07
	0.92(0.14)	0.02	3.70	0.56	0.16	4.42 ± 0.02
	1.71(0.12)	-0.06	4.20	0.54	0.16	4.93 ± 0.14
$4.0 \leq MM < 5.0$ $\overline{MM} = 4.5$	0.44(0.11)	0.02	4.09	0.70	0.18	4.97 ± 0.06
	0.71(0.03)	-0.13	3.95	0.74	0.28	4.42 ± 0.02
	0.87(0.09)	0.01	4.10	0.68	0.25	5.03 ± 0.02
	1.35(0.08)	-0.15	4.65	0.74	0.32	5.71 ± 0.06
$5.0 \leq MM < 5.5$ $\overline{MM} = 5.2$	1.58(0.07)	0.07	4.69	0.75	0.30	5.74 ± 0.13
	0.39(0.06)	-0.01	4.47	0.75	0.24	5.46 ± 0.11
	0.66(0.05)	-0.02	4.37	0.82	0.33	5.52 ± 0.03
	0.79(0.03)	0.08	4.38	0.84	0.36	5.58 ± 0.08
	1.20(0.08)	-0.03	4.98	0.82	0.36	6.16 ± 0.04

\bar{p}_{\perp} : Average transverse momentum of the forward proton in GeV/c; the half-width is in parenthesis
 \overline{MM} : Average missing mass in GeV in the range of missing mass as indicated.
 δN_{MM} : Correction of the average multiplicity due to the adjustment of \overline{MM} to the nominal value.
 \bar{N}_0 : Charged multiplicity determined by PIRACK and corrected by δN_{MM} .
 δN_1 : Correction of charged multiplicity using charge conservation.
 δN_2 : Correction of charged multiplicity for losses of two particles with opposite charge.
 \bar{N}_{CH} : Final mean charged multiplicity, and statistical and random systematic error.

The data in Fig. 2 suggest that some new phenomenon may be occurring in PP collisions when one of the final state protons emerges with a $p_{\perp} > 1 \text{ GeV/c}$; this phenomenon manifests itself in an increasing multiplicity for a fixed \overline{MM} . In order to gain further insight into possible mechanisms we have examined two more properties of the data: (1) the two-body effective mass distributions of the negative particle in the VS - assuming it is a π^- - with the HMS trigger proton and (2) the fraction of the particles in the VS that are on the side of the beam opposite to the HMS proton. For $\overline{MM}=2.6 \text{ GeV}$ and $\bar{p}_{\perp}=1.9 \text{ GeV/c}$, we find that the effective mass distribution has an average value of 3.8 GeV and that only 13% of the masses are smaller than 1.8 GeV. This result is consistent with a calculation based on the assumption that only the target proton is excited in the collision and subsequently decays according to phase space into five bodies [7]. For the fraction of the particles opposite the HMS proton we get 83%; the target excitation calculation [7] yields 86%.

The prediction of the multiperipheral model is in marked contrast to the data; for a fixed MM this model [8] gives an \bar{N} which decreases as $\ln(a+b p_{\perp}^2)$ [2]. Assuming that the events we are detecting involve only target fragmentation, the observed effect is also unexpected in the framework of a nova model, which gives $\bar{N} \sim MM$ with no dependence on p_{\perp} . It is worth noting however that the cross-section [9] for obser-

$p_{\perp} \sim 2$ GeV/c we are observing events that occur with a frequency 10^{-5} of events at $p_{\perp}=0$ GeV/c and 10^{-3} of events at $p_{\perp}=1$ GeV/c. It is conceivable, for example, that beam proton fragmentation or double-nova excitation occurring at $p_{\perp}=1.0 \rightarrow 1.5$ GeV/c (and hence having a much larger cross-section) could contribute to an HMS proton with $p_{\perp}=2$ GeV/c through a rare decay configuration. It seems clear that the calculation of such a contribution would be very sensitive to details of the nova model. If, as indicated by data at NAL energies [10], one needs a combination of multiperipheral and diffraction dissociation (nova) models then it may be possible to obtain our effect if the cross-sections for the two mechanisms have different p_{\perp} dependencies.

In the limiting fragmentation picture [11], the proton is an extended object of limited rigidity, and an increase of \bar{N} with p_{\perp} is expected and has been conjectured [12] to be (assuming there is enough available energy)

$$\bar{N} \approx \frac{p_{\perp}}{\langle p_{\perp} \rangle} \quad (2)$$

where $\langle p_{\perp} \rangle$ is the average transverse momentum in hadron-hadron collisions [13].

A bremsstrahlung mechanism [14] of pion production would also favor increasing \bar{N} ; how such pictures alone would give constant \bar{N} for $p_{\perp} < 1$ GeV/c is not obvious.

In conclusion, we have observed a sharp increase of \bar{N}_{CH} in PP collisions at 28.5 GeV/c when p_{\perp} to the trigger proton is larger than 1 GeV/c. There is an indication from the data that one is observing mainly target fragmentation, at least for $MM < 3$ GeV. The observed dependence of \bar{N}_{CH} with p_{\perp} is not predicted by existing models. Whether one is seeing evidence of some new phenomenon associated with close collisions, e.g. proton substructure, is a matter of speculation; what does seem clear is that this is an important new area of investigation.

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- $$\bar{N}_{CH} = \frac{2}{3} \frac{p_{\perp}}{\langle p_{\perp} \rangle} \quad \text{hence}$$
- $$\left(\frac{d\bar{N}_{CH}}{dp_{\perp}} \right)^{-1} = \frac{3}{2} \langle p_{\perp} \rangle = .6 \text{ GeV/c}$$
- a crude evaluation of $\left(\frac{d\bar{N}_{CH}}{dp_{\perp}} \right)^{-1}$ from the data of Fig. 2 for $p_{\perp} > 1$ GeV/c yields 0.7 GeV/c.
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