CHARGED PARTICLE MULTIPLICITIES AT THE CERN SPS COLLIDER

UA5 Collaboration

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Abstract

First results from UA5 on charged particle multiplicities from $p\bar{p}$ interactions at $\sqrt{s} = 540$ GeV are presented. A value of 27.4 ± 2.0 is obtained for the mean charged multiplicity $\langle n_{ch} \rangle$ of produced hadrons. This excludes an $s^{1/4}$ behaviour of $\langle n_{ch} \rangle$ in going from ISR to Collider energies, but is not in disagreement with an extrapolation using a quadratic fit in $\ln s$ to previous lower energy data up to ISR energies.

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Introduction - The CERN SPS Collider has extended the rapidity range of hadronic interactions from 8.4 units at the highest ISR energy to 12.7 units at the Collider c.m. energy $\sqrt{s} = 540$ GeV. If multiplicities of hadron production were to grow approximately as $\ln s$ we would expect an $\sim 50\%$ increase in the charged hadron multiplicity over this energy range. It is known from the ISR experiment of Thomé et al. [1] that the charged hadron multiplicity grows faster than $\ln s$, for the best fit to the data a $\ln^2 s$ term being required.

In cosmic ray experiments there have been indications [2] of events having a very high hadronic multiplicity which could indicate a still more rapid increase with s of the multiplicity. However, a recent balloon flight emulsion chamber experiment, studying hadronic interactions at a laboratory energy of ~ 20 TeV [3], finds a mean charged multiplicity consistent with an extrapolation of the fit of Thomé et al. mentioned above. In cosmic ray experiments, with primary flux falling off as $\sim E^{-1.7}$, E being the incident laboratory energy, different detector thresholds might significantly change the phenomena under study.

In view of these conflicting results from the cosmic ray data, the Collider experiments have an opportunity to improve our understanding by providing measurements based on well-controlled experiments in this energy region. In this paper we present the first results on the topological description of $p\bar{p}$ interactions at the Collider energy. The results are based on 340 completely measured and reconstructed events. The data come from a detector consisting of a pair of streamer chambers, 6 m long, placed above and below the beam pipe in the LSS4 experimental area of the CERN SPS Collider. The detector covers almost 4π in solid angle, and is triggered by planes of scintillator hodoscopes at either end. The triggered data is essentially non-diffractive, as described in the foregoing paper [4]. More information about the experimental set-up, trigger run conditions and the data analysis procedures as well as results concerning rapidity distributions are given there.

Analysis of the data - The dashed histogram of fig. 1(a) shows the charged multiplicity distribution of the raw data which were obtained after associating primary tracks to the interaction vertex. The main source of background to have been removed is electron or positron tracks originating from γ -rays which convert in the beam pipe. Of the tracks found to point back to the primary vertex typically 20% originate from this source. An algorithm was therefore developed to separate the true primary tracks from these secondaries by reconstructing secondary vertices in the beam pipe, making the appropriate small corrections. The observed primary multiplicity is typically 75% of the true multiplicity because of acceptance losses. Corrections have been made for these acceptance losses using a Monte-Carlo simulation.

Our Monte-Carlo program [4] generates events according to p_t -limited phase-space and a KNO distribution following the parametrization of Slattery [5]. It then tracks the particles through the detector configuration. These simulated tracks were analyzed by the same program chain as the real tracks. Fig. 1(a) shows as the full histogram the distribution resulting from this procedure. The two distributions are compatible. Table 1 shows the mean value and the dispersion obtained from the measured distribution before corrections are applied.

Fig. 1(b) shows the multiplicity distribution corrected for acceptances. The values of the mean charged multiplicity and the dispersion for this distribution are also given in table 1 for comparison. The KNO curve using the parameters given by Slattery [5] is superimposed on the distribution.

An independent estimate of the average observed charged multiplicity $\langle n_{ch} \rangle$ is obtained by integrating our pseudorapidity distribution given in [4]. The value obtained is 25.2 ± 1.4 . The Monte-Carlo simulation suggests that $6 \pm 3\%$ of the charged particles produced non-diffractively have $|\eta| > 5$. Taking this into account, the corrected mean charged multiplicity is therefore

$$\langle n_{ch} \rangle^{nd} = \sum n \sigma_n^{nd} / \sigma^{nd} = 26.8 \pm 2.1 ,$$

where the superscript nd indicates that our trigger excludes single diffraction dissociation. The above value is also given in table 1. Our best estimate is $\langle n_{ch} \rangle^{nd} = 27.4 \pm 2.0$ obtained by averaging the two values in table 1. The fit to the ISR data of Thomé et al. [1] using an $s^{1/4}$ dependence gives $\langle n_{ch} \rangle \approx 40$, a number which even at this stage we can rule out.

Fig. 2 shows the dependence of $\langle n_{ch} \rangle$ on s for several FNAL [6] and ISR [1] experiments. The data points are well described by the parametrization $\langle n_{ch} \rangle = a + b \ln s + c \ln^2 s$ determined by Thomé et al. [1]. The value of $\langle n_{ch} \rangle$ for a recent balloon flight experiment [3] also lies well on the extrapolated curve. However, since our measured value excludes the single-diffractive cross section it cannot be compared directly with the other experiments which give a value of $\langle n_{ch} \rangle$ for the whole inelastic cross section.

For FNAL data [6] and for our earlier ISR experiment [7] the values of $\langle n_{ch} \rangle^{nd}$ are also shown in fig. 2. Judging from the observed difference between $\langle n_{ch} \rangle^{nd}$ and $\langle n_{ch} \rangle$ over their energy range, the difference between our measured value and the extrapolation of Thomé et al. can easily be accounted for by a single diffraction dissociation component.

To estimate the influence of diffraction dissociation [8,9] we assume that, as observed at the ISR, elastic scattering and single diffraction dissociation each contributes 18% to the total cross section. Making the extreme assumptions for the mean charged multiplicity $3 \leq \langle n_{ch} \rangle^{sd} \leq 1/2 \langle n_{ch} \rangle^{nd}$, where the superscript sd denotes single diffraction dissociation, this leads to an estimate for the average inelastic charged multiplicity in the range $21 \leq \langle n_{ch} \rangle \leq 27$, in reasonable agreement with the prediction $\langle n_{ch} \rangle \approx 25$ of Thomé et al. This result puts in doubt speculations arising from cosmic ray studies about very high average multiplicities at Collider energies. We do observe events of very high multiplicity as may be seen from fig. 1(a) and 1(b), but the high multiplicity tail of the distribution needs further study.

Multiplicity dependence of pseudorapidity distributions - Fig. 3(a) shows our normalized pseudorapidity distributions for different intervals of the corrected observed multiplicity. For lower multiplicities ($n_{ch} \leq 30$) the distributions are almost flat. Going to higher multiplicities ($n_{ch} \leq 50$) the distributions develop an enhancement around $|\eta| = 1.5$ with a clear indication of lower values in the central region. This observation of lower values in the central region can be indicative of either a change in the relative particle composition ($\pi/K/N$) or an increase in the $\langle p_t \rangle$ or both.

Fig. 3(b) shows the dependence of the central ($|\eta| \leq 1$) pseudorapidity density on multiplicity n_{ch} . It grows linearly over the entire range.

Summary - our first results on a topological description of $p\bar{p}$ interactions show a number of phenomena, some expected and some unexpected.

- The average charged multiplicity $\langle n_{ch} \rangle$ does not grow as fast as $s^{1/4}$ from ISR to Collider energies.
- The parametrization of Thomé et al. for lower energies leading to $\langle n_{ch} \rangle \approx 25$ at our energy is appropriate to account for the observed s -dependence after we allow for single diffraction dissociation.
- The pseudorapidity distributions for different intervals of n_{ch} are almost flat up to $n_{ch} \approx 30$. At higher multiplicities the distribution develops an enhancement around $\eta = 1.5$.
- Our charged multiplicity is compatible with KNO scaling at this stage, but more accurate data are evidently needed at high multiplicities to confirm this hypothesis.

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TABLE 1

Values of $\langle n_{ch} \rangle$, $D = [\langle n(n-1) \rangle - \langle n \rangle^2]^{1/2}$ and $\langle n_{ch} \rangle/D$ obtained from the measured charged particle multiplicity at $\sqrt{s} = 540$ GeV. The left-hand column refers to the measured distributions before corrections were applied. The corrected values appear in the next two columns: firstly we give the values under our trigger conditions i.e. single diffraction excluded, and then in the last column we give values of $\langle n_{ch} \rangle$ allowing for a diffractive component (see text). The results labelled (a) are after unfolding the smearing of multiplicity due to acceptance limitations and (b) from a simple integration of the pseudorapidity distribution.

Quantity	Raw data	Corrected data	
		Single diffraction dissociation excluded	Single diffraction dissociation allowed for
$\langle n_{ch} \rangle$	20.0 ± 0.7	28.0 ± 2.0^a 26.8 ± 2.1^b	21 to 27
D	11.2 ± 0.5	12.5 ± 1.7^a	-
$\frac{\langle n_{ch} \rangle}{D}$	1.8 ± 0.2	2.2 ± 0.3^a	-

FIGURE CAPTIONS

Fig. 1 (a) Charged particle multiplicity for raw data obtained in this experiment by associating observed primary tracks to the interaction vertex, compared with a Monte-Carlo prediction following KNO scaling obtained after tracking through our detector.

(b) Measured multiplicity distribution corrected for acceptances, with KNO prediction superimposed.

Fig. 2 Dependence of $\langle n_{ch} \rangle$ upon $\sqrt{s}$ as measured in lower energy experiments together with the Thomé et al. [1] fit of the form $\langle n_{ch} \rangle = a + b \ln s + c \ln^2 s$ to ISR and lower energy data. The UA5 data point reported here is for single diffraction dissociation excluded, and several lower energy non-diffractive values are also shown for comparison.

Fig. 3 (a) Normalized pseudorapidity distributions for various intervals of corrected observed charged multiplicity obtained in this experiment.

(b) Dependence of central pseudorapidity density on n_{ch} .

— Fig.1 —

— Fig. 2 —

— Fig. 3 —

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