FIRST RESULTS ON COMPLETE EVENTS FROM $p\bar{p}$ COLLISIONS

AT THE CM ENERGY OF 540 GeV

UA5 Collaboration

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Abstract

First results from the UA5 detector on charged particle production at $\sqrt{s} = 540$ GeV in the pseudorapidity range $|\eta| < 5$ are presented. The central region pseudorapidity density is 3.0 ± 0.1 for non-diffractive events. The central width of the observed η -distribution is narrower than expected from a simple extrapolation of ISR data, suggesting an increase in the mean p_t for hadron production.

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Introduction - The successful operation of the CERN SPS Collider has opened a new energy regime in the study of hadronic interactions [1]. During the Collider run of 21-22 October 1981, the UA5 streamer chamber detector took data on ~ 3000 $p\bar{p}$ interactions. This was followed by a run from 5-10 November from which about a further 13 000 complete events resulted. The characteristic feature of the UA5 detector is visual recording of produced charged particles over almost the complete 4π solid angle [2]. We have observed and analysed even events in which more than 100 tracks were clearly seen in the detector.

There have been suggestions [3] in several cosmic ray experiments that hadronic interactions at Collider energy could show significant deviations from reasonable extrapolations of the FNAL [4] and ISR data [5,6], particularly in the direction of higher multiplicity. It is therefore of great interest to know to what extent the observed features of the new Collider data support these suggestions. First results on these questions are the main subject of this and a following paper [7] from the UA5 detector.

In this paper we outline aspects of the detector, the data-taking and analysis, and present the results for charged particle pseudorapidity ($\eta = -\ln \tan \theta/2$) distributions over the range $|\eta| < 5$, including a comparison with lower energy data. The following paper is devoted to our results concerning multiplicities.

The detector - A description of the UA5 detector as installed in the LSS4 experimental area of the SPS Collider is given in ref. [2]. Two 6 m long streamer chambers were placed one above and one below a corrugated elliptical beam pipe of 0.4 mm thick stainless steel, such that the visible parts of the chambers were separated by 9 cm. The homogeneity of the streamer chambers gave good track quality over the whole length of both chambers and allowed us to study charged particles with $|\eta| < 5$. Each chamber was viewed by three stereoscopic cameras: a main camera at each end viewing slightly more than half of the chamber at a demagnification of 50, and a central supplementary camera viewing the whole chamber at a demagnification of 80. Image intensifier tubes of gain ≈ 2000 were used

with each camera allowing us to run the streamer chambers with small streamers (≈ 5 mm long) and thus obtain the necessary two-track resolution of 2-3 mm. There was no magnetic field around the streamer chambers so the observed tracks are straight lines spreading out radially from the interaction point.

Run conditions - Typically one bunch of $\approx 5 \cdot 10^{10}$ protons was colliding in our intersection region LSS4 with one bunch of initially $\approx 10^9$ antiprotons, giving a starting luminosity of $2 \cdot 10^{25} \text{ cm}^{-2} \text{ s}^{-1}$. The luminosity lifetime was usually limited by the lifetime of the antiproton bunch which varied from one to ten hours. The decay of luminosity could be correlated well with the varying trigger rate using the fraction of beam-beam events found on the film.

Because we wanted to trigger on as large a fraction as possible of the inelastic $p\bar{p}$ cross section, we were obliged to use a "minimum bias" trigger. At each end of the chambers there was a large modular scintillation counter hodoscope and a small annular one mounted close to the beam pipe. The low luminosity made it necessary to require at least one hit at each end to reduce background triggers to an acceptable proportion, thus excluding single diffraction dissociation reactions from our event sample. The trigger conditions yielded on average $\sim 15\%$ of beam-beam interactions amongst the pictures in the October run analyzed in this and the following paper.

Data analysis - In view of the observed complexity of the events and the possibility of unusual phenomena being observed, we have analyzed this first sample of data by two completely independent methods. The agreement we find between the two techniques gives us confidence in the results.

The first method involved a very careful scan of ~ 100 events, carried out by physicists, in which tracks pointing to the primary vertex were identified, and their pseudorapidities determined using a template. Clear cases of e^+e^- pairs from photon conversions were eliminated. the identification of primary track candidates using this method was fairly unambiguous for $|\eta| \leq 3$, with an accuracy of ≈ 0.1 units in rapidity. Beyond $|\eta| = 3$ the data had to be corrected as described below.

In the second approach the film was first scanned in order to eliminate background events. Each track of the events found was digitized, and reconstructed in space with the analysis program already tested at the ISR [6], in which we analyzed pp and $p\bar{p}$ data at $\sqrt{s} = 53$ GeV. Our experience in this experiment was of great value in allowing us to measure and analyse SPS data quickly and reliably. The sample of measurements used here amounts to ≈ 350 events involving a total of $\sim 17\,000$ tracks.

In order to extract the true distributions of primary charged particles it was necessary in either method to correct the data for the acceptance of the apparatus, the effects of secondary interactions, γ conversions and strange particle decays, and for scanning and measuring losses. In the case of the scanning method the acceptance corrections ($\approx 25\%$) were made analytically and the corrections for the γ conversions ($\approx 13\%$) were calculated knowing the amount of material in the apparatus, assuming all γ 's come from decay of π^0 's and that $\pi^0/\pi^{ch} = 0.5$. The corrections ($\approx 5\%$) for strange particles decaying before entry to the chambers were estimated assuming a K/ π ratio of 0.2.

In the case of measured events, a computer program was used to separate the primary vertex from possible secondary vertices occurring in the beam-pipe, and to classify primary and secondary tracks accordingly. This program had been optimized using ISR data, and has been checked using Monte-Carlo simulations of Collider events with a variety of event generators. From these studies we are convinced that $\sim 90\%$ of primary tracks are immediately correctly identified; the remaining 10% are confused with secondaries, but a cut which separates these statistically was able to reduce the uncertainty on the number of primaries to $< 5\%$. The Monte-Carlo program corrects for the remaining uncertainty and for the acceptance of the apparatus, for secondary nuclear interactions, decays, multiple scattering, pair conversions, bremsstrahlung, δ -rays down to 1 MeV and for measurement errors.

An important correction in both methods is for trigger efficiency. Monte-Carlo calculations indicate clearly that single diffractive events would be largely excluded by our two-arm trigger since a recoil proton would pass down the beam-pipe. Except when indicated otherwise the

following results therefore refer to inelastic events, with the single diffraction dissociation component excluded. We estimate that only $\sim 5 \pm 3\%$ of non-diffractive inelastic events have been lost by our trigger, these being of very low multiplicity.

When running at very low luminosity it is important to ensure that there is no contamination due to background events. Our high precision in vertex reconstruction (2-3 mm in space) allowed us to eliminate beam-halo interactions in the beam pipe. After a cut requiring the interaction to take place inside the beam-pipe, the vertices are well confined to the nominal beam position in the transverse plane and form clusters of length 35 cm along the beam direction. The length and positions of these clusters give a direct check on the expected overlap of the two bunch profiles and the measured time of bunch crossings. To check for beam-gas background we examined the forward-backward asymmetry of the events. Since the intensity of protons is much higher than for antiprotons, background events will tend to be proton-induced, and point in the proton direction. The asymmetry seen in the data is entirely explained in terms of our acceptance. We therefore conclude that the data sample used here is free of background down to the 1% level.

Results - The corrected pseudorapidity distribution folded about $\eta = 0$ is shown in fig. 1(a). We see that the distribution is generally flat over the region $|\eta| < 3$, where the average number of particles per unit rapidity is 3.0 ± 0.1 . For comparison, we obtained [6] an average value 1.75 ± 0.07 for $|\eta| < 2$ at $\sqrt{s} = 53$ GeV using the same detector at the ISR. In a cosmic ray balloon experiment at approximately $\sqrt{s} \approx 180$ GeV [8], in which the charged secondaries were detected with good efficiency, the value obtained is 2.6 ± 0.5 . These average values are shown in fig. 2, together with values of $1/\sigma(d\sigma/d\eta)(\eta = 0)$ obtained at different ISR energies [5], and lower energy FNAL values [4]. In all these experiments no trigger condition requiring at least one charged particle in the acceptance region of the central rapidity range was made, as is often the case with counter experiments. A $\ln s$ extrapolation of all lower energy data would suggest a central region value of $1/\sigma(d\sigma/d\eta)$ of ~ 2.6 instead of the 3.0 ± 0.1 observed with our experimental set-up. This difference could well be accommodated by the possible $18 \pm 5\%$ single

diffraction dissociation contribution suggested at our energy [9] to which our trigger was insensitive, leading to an equivalent renormalization of the distribution.

The central plateau in rapidity in fig. 1 appears to extend to ± 3 units, so that by $|\eta| = 4.25$ the distribution has fallen to half its maximum value. For comparison at $\sqrt{s} = 53$ GeV [6] the plateau was ± 2 units wide, and fell to half maximum at $|\eta| \approx 3.25$. So we observe that the width of the plateau has grown by only ~ 2 units in going from $\sqrt{s} = 53$ GeV to $\sqrt{s} = 540$ GeV, whereas the separation of the two beam particles has increased by 4.6 units over this energy. Thus, the central plateau has not spread as much as it could have done on kinematic grounds.

Introducing the conventional cylindrical phase space description (incorporating leading baryons) with $\langle p_t \rangle = 350$ MeV/c which has been checked to fit our ISR data well, a Monte-Carlo simulation leads to the dashed curve of fig. 1(b). We see immediately that the central rapidity plateau is expected to extend to ≈ 5 units in such a model. Furthermore, the curve predicts a significant dip near $|\eta| = 0$. It is evident from the comparison that such a description cannot account for the data. We would have to increase $\langle p_t \rangle$ to ≈ 500 MeV/c, as shown in the solid curve, to get reasonable agreement. In the cosmic ray data [8] referred to earlier, a reliable measurement of energy is done only for the γ -rays in the forward hemisphere; from these measurements $\langle p_T \rangle$ for π^0 's was found to be 400 ± 20 MeV/c.

Summary - We have measured non-diffractive charged particle production in $p\bar{p}$ interactions at $\sqrt{s} = 540$ GeV over the pseudorapidity range $|\eta| < 5$. An average value for the central rapidity density of 3.0 ± 0.1 has been found. The width of the observed η distribution as expressed by the FWHM has grown by 2 units over this range of s . A conventional cylindrical phase space model of low p_t hadron production could accommodate this, for example, by increasing the $\langle p_t \rangle$ from ~ 350 MeV/c to 500 MeV/c.

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FIGURE CAPTIONS

- Fig. 1 (a) Corrected pseudorapidity distributions for $\sqrt{s} = 540$ GeV folded about $\eta = 0$, from 100 events template-measured by physicists (histogram) and from 340 events passed through our digitizing and analysis procedures (solid points). The errors are statistical only.
- (b) Data from 340 events at $\sqrt{s} = 540$ GeV compared with earlier UA5 data obtained at the ISR at $\sqrt{s} = 53$ GeV (open points). The dashed and dot-dashed curves are predicted from p_t limited phase-space for $\langle p_t \rangle = 350$ MeV/c. The solid curve for $\sqrt{s} = 540$ GeV is from the same model but for $\langle p_t \rangle = 500$ MeV/c.

- Fig. 2 Charged particle density in pseudorapidity near $\eta = 0$ from various experiments up to Collider energy. Our Collider value is for single diffractive events excluded. The straight line is drawn by eye to indicate a possible $\ln s$ dependence of the lower energy data. The values from the ISR of ref. [5] were obtained by reading off at $\eta = 0$ from fig. 6 of that reference.

— Fig. 1 —

— Fig. 2 —