PSEUDORAPIDITY DISTRIBUTION OF CHARGED PARTICLES IN DIFFRACTION
DISSOCIATION EVENTS AT THE CERN SPS COLLIDER

UA4 Collaboration

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ABSTRACT

The reaction $\bar{p}p \rightarrow \bar{p}X$ was studied as a function of the mass M of the system X at the centre-of-mass energy $\sqrt{s} = 546$ GeV in the kinematical region where diffraction dissociation dominates. The pseudorapidity distribution of charged tracks, produced in the fragmentation of the system X , is well described within the limits of cylindrical phase space. The fragments of the X -system behave very similarly to the products of non-diffractive inelastic collisions at $\sqrt{s} = M$.

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Evidence for single diffraction dissociation at the CERN SPS Collider was reported earlier [1]. Further information on the features of diffraction dissociation events is reported in this letter. The reaction $\bar{p}p \rightarrow \bar{p}X$ was studied at the centre-of-mass energy $\sqrt{s} = 546$ GeV. The antiproton scattered at very small angles was observed in a spectrometer consisting of very forward detectors placed in "Roman pots" beyond machine quadrupoles [2]. Charged particles produced by the proton fragmentation were observed in a vertex detector consisting of the UA4 forward drift chamber telescopes [2] and of the central detector of the UA2 Collaboration [3]. This system covered the full angular range, with the exception of two small angle regions and of two gaps at intermediate angles, corresponding to the pseudorapidity intervals $|\eta| \geq 5.6$ and $1.7 \leq |\eta| \leq 2.5$, respectively.

Data were taken at a typical luminosity of about $10^{28} \text{ cm}^{-2} \text{ s}^{-1}$, when the machine optics at the intersection region was in the low- β mode. The vast majority of the data were taken using the "Roman pots" detectors and the UA4 forward telescopes only [1]. The UA2 central detector was available for read-out with a diffractive trigger only for a limited amount of running time.

The trigger required a particle through the two 'Roman pot' telescopes on the outgoing antiproton side in coincidence with at least one charged particle in the pseudorapidity range $2.5 \leq \eta \leq 5.6$ in the proton hemisphere [1,2]. Events were analysed by requiring the presence of an interaction vertex reconstructed by the vertex detector and a single track in the two 'Roman pot' telescopes.

The acceptance and efficiency of the combined UA2/UA4 tracking system, as a function of η , was evaluated by a Monte-Carlo calculation taking into account the dead space due to the chamber frames and the chamber efficiencies. It was checked that the η -distribution obtained with an inclusive non-diffractive trigger (left-right coincidence in the interval $3.0 \leq |\eta| \leq 5.6$) was in agreement with the distributions measured by UA5 [4] and UA1 [5].

The antiproton momentum was determined from the deflection of its trajectory by the magnetic field of the machine quadrupoles. The observed momentum resolution, evaluated by analysing elastic scattering events [1,2], has a r.m.s. value of 0.6%. Defining the variable x , as $x = p/p_0$, where p is the measured antiproton momentum and p_0 the beam momentum, the mass M of the system X is given by $M^2(1-x)s$. The observed momentum resolution implies an error on the mass given by $\Delta M = k/M$, with $k \approx 900 \text{ GeV}^2$.

Inelastic diffractive processes can take place if the coherence condition is satisfied, i.e. if the longitudinal momentum transfer is smaller than the inverse of the strong interaction radius [6]. As the centre-of-mass energy increases, this condition becomes satisfied for larger and larger masses. The validity of such classical argument at the energy of the Collider, i.e. the diffractive production of states with masses of the order of 100 GeV, was shown by the data reported earlier [1], where the typical quasi-elastic peak for $M^2/s \leq .04$ was clearly visible in the invariant differential cross section. At fixed t and for $0.01 \leq M^2/s \leq 0.04$, the $1/M^2$ dependence of the mass distribution already seen in the FNAL and ISR energy range was shown to persist for the new very high mass diffractive states.

The capability of the SPS Collider to produce very large diffractive masses opens the possibility of discriminating between different (extreme) pictures of the diffraction dissociation process. In particular, the pseudorapidity distribution of charged particles for high-mass diffractive states provides a useful tool for studying the mechanism of diffractive production and decay [7]. There are basically two groups of models for diffraction dissociation, predicting two distinct shapes of the pseudorapidity distribution around the kinematic central value $\bar{\eta} = \log(\sqrt{s}/M)$. Fireball-type models, which assume isotropic decay of the diffractive states, predict diffractive clusters of constant rapidity width ($\Delta\eta \approx \pm 0.7$), independent of the mass of the dissociating state. Multiperipheral-type models, on the other hand, predict clusters whose width increases logarithmically with the mass as $\Delta\eta = \pm \log(M/m)$, where m is the proton mass. In such a case the clusters stretch from the maximum available value of rapidity, $\log(\sqrt{s}/m)$ to an inner edge $\eta_{\min}$ given by $\log(m\sqrt{s}/M^2)$.

It was suggested [7] that at ISR energies data from the Pisa-Stony Brook experiment [8] could be interpreted with distributions of constant width. Results from the CHLM collaboration [9], however, contradicted this interpretation supporting the notion of stretching clusters. The large rapidity interval made available by the CERN SPS Collider offers the possibility of an unambiguous and conclusive statement.

Pseudorapidity distributions measured at four-momentum transfers between 0.5 and 0.8 GeV^2 , for different values of the diffractive mass M , as measured by the recoil technique in the antiproton spectrometer, are shown in fig. 1. An average mass value $\langle M \rangle$ was assigned to each mass interval taking into account the observed $1/M^2$ behaviour and the effect of the mass resolution. Clusters are centered at the expected value and their width does increase with M . The observed position of the inner edge is in good agreement with the value $\eta_{\min}$, as predicted by longitudinal phase space (multiperipheral-type) models. The effect is less evident for the smallest mass interval, where the η -distribution is rather distorted; here, however, the mass resolution is quite poor and contributions from widely different masses are mixed together.

The similarity of the dissociation of a diffractively produced system of mass M to the hadronization resulting from collisions at c.m.s. energy $\sqrt{s} = M$ is further illustrated in fig. 2 and fig. 3. A compilation, [4,5], of the charged particle pseudorapidity density, $dn/d\eta$ at $\eta = 0$, as a function of $\sqrt{s}$, for non-diffractive hadronic collisions, is shown in fig. 2. Values of $dn/d\eta$ around $\eta = \bar{\eta}$ were estimated from the data of the present experiment and plotted in fig. 2 at $\sqrt{s} = M$. It appears that the central rapidity density of the diffractive clusters rises with M in a way which is very similar to that of the rapidity plateau of non-diffractive inelastic events.

Integration of the pseudorapidity distributions of fig. 1 yields the average multiplicity $\langle n_{\text{ch}} \rangle$ of charged secondaries produced in the fragmentation of the X-system. Data from the present experiment are plotted in fig. 3 at $\sqrt{s} = M$ together with a compilation [10] of $\langle n_{\text{ch}} \rangle$ as a function of $\sqrt{s}$ for non-diffractive inelastic collisions. The growth of $\langle n_{\text{ch}} \rangle$ with M closely follows the observed rise of the charged multiplicity with $\sqrt{s}$.

The results reported in this letter show quite clearly that the fragmentation of a diffractively produced system of mass M is very similar to the well known hadronization process that takes place in a hadronic collision with c.m.s. energy equal to M . As a consequence the average transverse momentum of the secondaries should also be similar to that observed in hadronic collisions with the same available energy.

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FIGURE CAPTIONS

- Fig.1 Pseudorapidity distributions of charged tracks from the fragmentation of diffractive states. Data are binned in mass intervals with average value $\langle M \rangle$. The arrows show the expected position of the centre of the cluster $\bar{\eta}$ as given by kinematics and that of the inner edge $\eta_{\min}$ as predicted by longitudinal phase space.
- Fig.2 Charged particle density in pseudorapidity. The UA4 results for diffractive clusters evaluated near $\eta = \bar{\eta}$ are plotted at $\sqrt{s} = M$ together with the data near $\eta = 0$ for non-diffractive inelastic events [4,5].
- Fig.3 Average charged multiplicity. The UA4 results for diffractive clusters are plotted at $\sqrt{s} = M$ together with data for non-diffractive inelastic events [10].

Fig. 1

Fig. 2