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SINGLE DIFFRACTION DISSOCIATION AT THE CERN SPS COLLIDER

UA4 Collaboration

Amsterdam¹-CERN²-Genova³-Napoli⁴-Pisa⁵

M. Bozzo^{3(*)}, P.L. Braccini^{5(**)}, F. Carbonara⁴, R. Carrara⁵,
R. Castaldi⁵, F. Cervelli⁵, G. Chiefari⁴, E. Drago⁴, M. Haguenaue²,
B. Koene¹, G. Matthiae⁴, L. Merola⁴, M. Napolitano⁴, V. Palladino⁴,
G. Sanguinetti⁵, G. Sciacca⁴, G. Sette³, R. van Swol¹, J. Timmermans¹,
C. Vannini⁵, J. Velasco² and F. Visco⁴

- 1 NIKHEF-H, Amsterdam, The Netherlands
- 2 CERN, European Organization for Nuclear Research, Geneva, Switzerland
- 3 Istituto di Fisica dell'Università e Sezione INFN, Genova, Italy
- 4 Istituto di Fisica Sperimentale dell'Università e Sezione INFN,
Napoli, Italy
- 5 Istituto di Fisica dell'Università e Sezione INFN, Pisa, Italy

ABSTRACT

The reaction $\bar{p}p \rightarrow \bar{p}X$ was studied at a centre-of-mass energy $\sqrt{s} = 540$ GeV by measuring the momentum spectrum of the antiproton. Data are presented in the four-momentum transfer range $0.5 < -t < 1.2$ GeV². The shape of the mass distribution of the system X shows a diffractive component as already observed at lower energies. The differential cross section scales approximately with energy when compared to the ISR data.

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(*) At present CERN Research Associate.
(**) Also at University of Perugia, Italy.

The reaction $\bar{p}p \rightarrow \bar{p}X$ was studied at the CERN SPS Collider at a centre-of-mass energy $\sqrt{s} = 540$ GeV, by detecting the antiproton and the charged decay products of the system X. The same experimental apparatus was used as for the measurement of elastic scattering [1] and of the total cross section [2]. The antiproton scattered at small angles is observed in a spectrometer composed of two arms placed symmetrically above and below the machine plane. In each arm the particle trajectories are measured at four different points by detectors placed inside movable section of the vacuum chamber ("pots").

The momentum of the antiproton is determined from the deflection of its trajectory by the magnetic field of the machine quadrupoles. Charged particles produced by the proton fragmentation are observed in a vertex detector which consists of two identical systems of three drift chambers telescopes placed symmetrically on the left and right side of the crossing region and covering angles from $\sim 0.5^\circ$ to $\sim 10^\circ$. The range in the pseudorapidity variable η covered by these detectors is from 2.5 up to 5.6.

Data were taken at a typical luminosity of $\sim 10^{28} \text{ cm}^{-2} \text{ s}^{-1}$ when the machine optics at the intersection region was in the low- β mode. For these optics the horizontal and vertical distributions of the interaction points at the crossing have r.m.s. spreads of about 0.1 mm.

The trigger required a particle through the two "pot" telescopes of either the upper or the lower arm in coincidence with at least one charged particle in the pseudorapidity range $3 < \eta < 5.6$ in the opposite hemisphere. In addition, events with charged particles on the antiproton side in the range $-5.6 < \eta < -4.4$ were vetoed in order to make the trigger more selective against background of halo particles. The events were analyzed by first requiring the presence of a vertex reconstructed from the tracks observed in the vertex detector. A single track was then demanded in both "pots" telescopes of either the upper or the lower arm, with no tracks in the other arm. About 35% of the triggers survived these selections.

The system accepts antiprotons with the vertical component of the production angle in the range $2.5 < \theta_V < 4.5$ mrad. The antiproton momentum was obtained from the measured vertical displacement of the particle trajectory at the detectors, by using the known values of the transfer matrices of the quadrupoles and imposing a constraint on the vertex position. The momentum resolution of the system was evaluated by analyzing elastic scattering events [1] which were collected at the same time and identified on the basis of the collinearity requirement between the left-going antiproton and the right-going proton. As shown in fig. 1(a), the observed momentum resolution has an r.m.s. value of 0.6% which is essentially determined by the measurement errors. Other sources of error give a negligible contribution. In fact the intrinsic momentum spread of the antiproton beam is a few times 10^{-4} and the integrated gradient of the quadrupole magnetic field is known to vary by less than 2.10^{-3} across the aperture.

The four-momentum transfer to the antiproton is calculated from the relation $-t = m^2(1-x)^2/x + 2 p_0^2 x (1-\cos\theta)$, where m is the proton mass, p_0 is the beam momentum, whose nominal value is 270 GeV/c, and θ is the observed production angle of the antiproton. The variable x is defined as $x = p/p_0$, where p is the measured antiproton momentum. The mass M of the system X is given by $M^2 = (1-x) s$. The acceptance of the apparatus, as obtained from Monte-Carlo calculation, is shown in fig. 1(b) for various values of t , as a function of x . The acceptance drops rapidly as x moves away from one, especially at low values of t , because the particle trajectories are bent towards the machine plane and miss the detectors. Thus, our apparatus allows the study of the reaction $p\bar{p} \rightarrow p\bar{X}$ in the kinematical region where x is close to one, i.e. where the diffraction dissociation mechanism is dominant.

The absolute normalization of the event rate was provided by two independent monitor systems consisting of scintillation counters placed symmetrically on the left and on the right side of the crossing point. The effective cross sections of the two monitors were 55% and 6.2% respectively, of the total cross section. The latter was taken as 67 mb on the basis of a measurement performed during the same experiment [2].

The data are presented in fig. 2 where the invariant differential cross section $(s/\pi) d^2\sigma/dt dM^2$ is shown as a function of the variable M^2/s for various values of t . In addition to the acceptance correction for the antiproton, a further normalisation correction of 25% was applied to account for (i) the loss due to the limited angular coverage for the detection of the system X (8%), (ii) event losses in the reconstruction program due to chamber inefficiencies (2%), (iii) absorption of the antiproton in the "pot" telescopes (3.8)% and (iv) the cut on the χ^2 of the antiproton momentum fit ($\sim 10\%$). The absolute normalization of these data is affected by an overall scale error of about $\pm 20\%$, half of which is due to the present uncertainty on the total cross section [2]).

These distributions clearly show the presence of the quasi-elastic peak at $M^2/s \lesssim 0.03$ which is typical of the inelastic diffractive process as demonstrated by earlier measurements at Fermilab and ISR. At the energy of the Collider, diffractive production of states with masses as large as 100 GeV is observed. This may be expected on the basis of the classical argument given by Good and Walker [3]. The inelastic diffractive process can take place if the coherence condition is satisfied: the longitudinal momentum transfer has to be smaller than the inverse of the strong interaction radius. As the centre-of-mass energy increases, this condition becomes satisfied for larger masses.

The ISR data [4,5] have demonstrated that for $M^2/s \gtrsim 0.01$ the invariant cross section scales, i.e. at fixed values of M^2/s and t , it is independent of the centre-of-mass energy. This property extends up to the Collider energy as can be seen from fig. 3 where the present data are compared to the M^2/s distributions at the same values of t , as measured at the ISR [4] in proton-proton interactions. It should be noted that the M^2/s resolution of the present data is very similar to that of the ISR experiment [4]. As discussed in ref. [5], the non-scaling of the differential cross section for $M^2/s \lesssim 0.01$ is at least partly kinematic in origin and due to the fact that the minimum mass that can be produced is independent of s . As a consequence, the position of the quasi-elastic peak in the variable M^2/s moves with energy as $1/s$. The present data follow this behaviour.

The ISR [4] and Fermilab [6] data have shown that at fixed t and for $M^2/s \lesssim 0.04$, the mass distribution decreases approximately as $1/M^2$, as expected if the mechanism described by the triple Pomeron graph is dominant. This same dependence is observed at the Collider energy. The two properties of scaling and $1/M^2$ dependence are exhibited in fig. 4 where our results on the non-invariant cross section $d^2\sigma/dt dM^2$, at $-t = 0.55 \text{ GeV}^2$ in the range $0.01 < M^2/s < 0.04$, are plotted as a function of M^2 together with ISR data [4] at the same value of t and in the same M^2/s range. The data which cover more than three orders of magnitude follow quite closely the $1/M^2$ dependence.

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FIGURE CAPTIONS

- Fig. 1 (a) The antiproton momentum resolution as determined from the analysis of elastic scattering events.
- (b) The acceptance of the system for inelastically scattered antiprotons is shown for different values of t as a function of x , the ratio of the antiproton momentum to the beam momentum.
- Fig. 2 The invariant cross section $(s/\pi)d^2\sigma/dt dM^2$ is shown for different values of t as a function of the variable $M^2/s = 1-x$. The t -bins are 0.1 GeV^2 wide.
- Fig. 3 The invariant cross section of proton-antiproton interactions at $\sqrt{s} = 540 \text{ GeV}$ for $-t = 0.55$ and 0.75 GeV^2 is compared to the proton-proton data at ISR energies from ref. [4] at the same t -values.
- Fig. 4 The non-invariant cross section $d^2\sigma/dt dM^2$ at $-t = 0.55 \text{ GeV}^2$ is shown as a function of M^2 together with proton-proton results from ref. [4]. Only data in the range $0.01 < M^2/s < 0.04$ are displayed.

Fig. 1

Fig. 2

Fig. 3

Fig. 4