A COMPARISON OF THE PRODUCTION OF π^0 -MESONS IN $p\bar{p}$ AND pp INTERACTIONS
AT THE CERN ISR

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ABSTRACT

A comparison of $p\bar{p}$ and pp interactions was made at $\sqrt{s} = 52.7$ GeV at the CERN ISR. The quantities compared were the charged and neutral multiplicities, the total neutral transverse energy, $\sum E_T$, up to 12 GeV, and the single π^0 inclusive cross-section up to $p_T = 5$ GeV/c. No significant differences were observed.

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Since antiprotons have been available in the ISR it has become possible to compare $p\bar{p}$ with pp collisions at the same centre-of-mass energy in the same detector, thus eliminating most sources of systematic uncertainties. The comparison described in this letter refers to the production of neutral particles, mainly π^0 -mesons, in the central region.

The apparatus, shown in fig. 1, consisted of a superconducting solenoid [1] providing a magnetic field of 1.4 T and enclosing a system of cylindrical drift chambers [2]. Four modules of lead-scintillator shower counters were also located inside the magnet. Each counter was segmented azimuthally into 8 counters. Each counter was subdivided in depth into a front and a back compartment. The counters were 14 radiation lengths thick and consisted of 16 layers of scintillator interleaved with layers of lead, 4 layers in the front compartment and 12 in the back. The energy deposited in each counter was recorded using photomultipliers at both ends of the front and back compartments. Each module was 1.5 m long, subtended 50° in azimuth and ± 1.2 units of rapidity, y , centred at $y = 0$. The detection of electromagnetic showers was completed by two lead-glass (SF 5) modules located outside the magnet in the angular region not covered by the shower counters. Each module consisted of a front array of 34 counters, each 4 radiation lengths thick, and a back array of 168 counters, each 17 radiation lengths thick. A cathode strip read-out multiwire proportional chamber (MWPC) was placed between the front and back arrays of each module for better shower localization. The angular acceptance of each lead-glass array was 45° in azimuth and ± 0.6 units of rapidity also centred around $y = 0$. The shower counters and lead glass were initially calibrated in an electron test-beam at the CERN PS. Subsequently the calibration of the shower counters and of the front glass was monitored using a system of light flashers (krytrons) distributing their light to the counters and to a reference counter using light fibres. The stability of the light output of the krytrons was monitored by comparing it, in the reference counter, with the light output of a NaI crystal on which a ^{137}Cs source was mounted. The calibration of the back glass [3] was monitored using NaI crystals doped with ^{241}Am .

A hodoscope of 32 scintillation counters (A) was located between the first and second drift-chamber modules. Two hodoscopes of 12 scintillation counters (B) were positioned just outside the solenoid against the external shell of the cryostat.

In the forward direction, telescopes of two scintillation counters (MM) were located one below and one above the beam pipe on each of the outgoing beams. Each of these four telescopes was sensitive to particles emitted with laboratory polar angles between 31 and 95 mrad, and was situated 1.4 m from the centre of the interaction region.

The $p\bar{p}$ data were collected at an average luminosity of $7 \times 10^{26} \text{ cm}^{-2} \text{ s}^{-1}$ and with very asymmetric beam currents of about 7 A in the proton beam and 2 mA in the antiproton beam. The basic trigger consisted of a total energy deposition in excess of 1 GeV in the lead glass plus shower counters. However, any trigger using counters only in the central region was contaminated by beam-gas events arising from the proton beam. In order to eliminate this background, the data described here were collected using an additional forward requirement in the trigger consisting of a tight coincidence between either of the proton beam MM telescopes and either of the antiproton beam MM telescopes. This MM requirement by itself was sensitive to 25% of the total cross-section. We stress that the results presented here do not refer to inclusive 90° data but to data biased by this forward requirement. The pp data, although not suffering from beam-gas contamination, were taken using an identical trigger. The $p\bar{p}$ data correspond to an integrated luminosity of $1.4 \times 10^{32} \text{ cm}^{-2}$.

Neutral particles (π^0 -mesons) were defined as clusters of energy of greater than 300 MeV. In the lead glass a cluster was defined as a matrix of at most 4×4 adjacent counters in the back array plus the associated front-array blocks. In the shower counters a cluster was defined as an energy deposition over at most 3 adjacent counters. In addition, at least 10% of the energy was required to be in the front compartment in order to reduce background from charged hadrons. For the inclusive cross-section measurement the additional requirement was made that

the clusters be separated from each other in azimuth by at least one counter. This requirement was not imposed in the total transverse energy, $\sum E_T$, analysis. The individual γ -rays from π^0 decays were not resolved. For each neutral cluster the centre-of-mass transverse momentum, p_T , was calculated. Since the drift-chamber information was not used in this analysis, this calculation was made assuming the event vertex to be at the centre of the interaction region.

As a check on the performance of the newly installed shower counters, pp data were collected without the MM requirement. The resulting π^0 invariant cross-section, calculated over the interval $-1.0 < y < 1.0$, is shown in fig. 2, together with measurements on $\pi^\pm$ production [4]. The π^0 values are about a factor of 2 higher at high p_T than the corresponding $\pi^\pm$ measurements. A detailed analysis of a subset of the data indicates that this is due to the large angular acceptance of a 3-shower counter cluster resulting in overlaps of 2 particles being labelled as a single π^0 . However, both pp and $p\bar{p}$ data should be affected equally so this should not affect the resulting comparison.

The total transverse neutral energy of an event, $\sum E_T$, was defined as the sum over all the energy clusters in an event of the quantity $|p_T|$. The mean multiplicity of A counters (which is related to the charged-particle multiplicity) and of neutral clusters is plotted in figs. 3a and b, respectively, as a function of $\sum E_T$. A linear rise with $\sum E_T$ is observed for both neutral and charged particles and for both pp and $p\bar{p}$ data. The absolute values of the two plots should not be compared because

- a) the threshold for a charged particle to set an A counter is much less than the minimum 300 MeV required for a neutral particle to form a cluster, and
- b) the neutral particles are in the trigger, whereas the charged particles are not.

The ratio of the pp and $p\bar{p}$ total transverse neutral energy spectra normalized to the same integrated luminosity is shown in fig. 4a. Whereas the individual spectra fall by 5 orders of magnitude between 1 and 12 GeV, the ratio remains close

to 1.0. The inclusive π^0 cross-section in the p_T interval $1 < p_T < 5$ GeV/c was calculated for the pp and $p\bar{p}$ data. The ratio of these two cross-sections is shown in fig. 4b. For $p_T < 2.5$ GeV/c the ratio is consistent with 1.0 in agreement with earlier results [5]. For $p_T > 2.5$ GeV/c a 40% increase in the ratio cannot be ruled out.

In conclusion, $p\bar{p}$ and pp collisions were compared at $\sqrt{s} = 52.7$ GeV using a total energy trigger which required in addition at least two charged particles at angles of about 1° to the beams. No significant differences were observed in charged or neutral multiplicities, inclusive π^0 cross-section, or total transverse neutral energy spectrum.

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Figure captions

- Fig. 1 : A view of the apparatus as seen along the beam direction.
- Fig. 2 : The neutral cluster data obtained in this experiment compared with the charged particle inclusive cross-sections of ref. 4.
- Fig. 3 : a) The average A counter multiplicity plotted as a function of $\sum E_T$.
b) The average neutral cluster multiplicity plotted as a function of $\sum E_T$.
- Fig. 4 : a) The ratio of the $\sum E_T$ spectrum obtained in $p\bar{p}$ collisions to that obtained in pp collisions.
b) The ratio of the π^0 inclusive cross-section obtained in $p\bar{p}$ collisions to that obtained in pp collisions.

Fig. 1

Fig. 2

(a)

(b)

Fig. 3

(a)

(b)

Fig. 4