A COMPARISON OF HADRON PRODUCTION IN $p\bar{p}$ AND pp COLLISIONS IN THE CENTRAL REGION AT $\sqrt{s} = 53$ GeV

The Axial Field Spectrometer Collaboration

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ABSTRACT

We have studied the inclusive production of the hadrons $\pi^\pm$, $K^\pm$, p , $\bar{p}$, Λ , $\bar{\Lambda}$, ρ , f , K^{*0} , $\bar{K}^{*0}$, and ϕ in the central region at the ISR, $\sqrt{s} = 53$ GeV, in both pp and $p\bar{p}$ collisions. Differences are observed only for $K^\pm$, p , and $\bar{p}$ production. We then study also correlations between low- p_T pp and $p\bar{p}$ pairs in the two types of collisions, separating the contribution from baryon pair production and from the incident particles (stopping protons). We observe a positive correlation between two stopping protons; between the production of two pairs, and between a stopping proton and a pair production, there are negative correlations.

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1. INTRODUCTION

In April 1981 the first $p\bar{p}$ colliding beam run took place in the ISR, providing a unique facility for making comparisons between $p\bar{p}$ and pp collisions at very high energy. The difference in the total cross-sections [1] is small, $\sigma_T(p\bar{p}) - \sigma_T(pp) \approx 1$ mb at $\sqrt{s} = 53$ GeV, and the global features of inelastic $p\bar{p}$ collisions are very similar to those already well known for pp collisions. We have previously compared single-particle production in the central region for $p_T < 1.5$ GeV/c [2], finding differences in the p_T and y distributions of identified $p(\bar{p})$, compared [3] event features as a function of total charged transverse energy E_T^c up to $E_T^c = 12$ GeV, and compared [4] unidentified hadron (and hadron-pair) spectra up to $p_T \approx 6$ GeV/c. In the latter studies [3,4] no significant differences between $p\bar{p}$ and pp collisions were found.

In this paper we report on a systematic comparison of central particle production, including resonances (ρ , f , K^* , ϕ) and baryons (p , $\bar{p}$, Λ , $\bar{\Lambda}$), extending a previous study [5] with only pp collisions. Channels which may be sensitive to $q\bar{q}$ annihilation (e.g. ϕ production) are of particular interest to compare in $p\bar{p}$ and pp ; in lower energy pp collisions $q\bar{q}$ annihilation does not contribute significantly to ϕ production [6]. From baryon/antibaryon distributions one obtains further information relevant to the mechanism of particle production. It is known from previous experiments [7,8] that a sizeable fraction of the low- p_T protons close to $y = 0$ in pp collisions does not come from baryon-antibaryon pair creation but is directly associated with the incoming baryon number. To the degree that such distinction makes sense, a comparison of p and $\bar{p}$ production in pp and $p\bar{p}$ collisions makes it possible, in principle, to disentangle these two sources of protons in the central region. We measure the amplitude of these components and investigate whether there is evidence for a positive correlation between protons originating from the fragmentation of the two beam particles. It has been suggested [9] that a positive correlation may exist, where the two protons "stop" each other, losing most of their energy through the emission of mesons.

2. APPARATUS AND DATA ANALYSIS

The experiment was performed with the Axial Field Spectrometer [10] (AFS) at the CERN Intersecting Storage Rings (ISR). For the present investigation only the cylindrical drift chamber, shown in fig. 1 of ref. [5], and scintillator hodoscopes were used. The drift chamber is situated in an axially symmetric magnetic field of 0.5 T. A cylindrical scintillator hodoscope is placed between the vacuum chamber and the drift chamber. It consists of 44 strips, each covering 8° in azimuth with a length of 0.6 m at a radius $r = 0.18$ m.

The drift chamber and its performance are described in detail elsewhere [10]. It is 1.4 m long, and extends radially from 0.20 to 0.80 m. It is segmented azimuthally in 4° sectors, each with 42 resistive sense wires, which provide the coordinates in the transverse plane from drift-time and the position along the sense wire from a measurement of the pulse-heights recorded at both ends. Particles are identified using the information on the ionization from the drift chamber. The truncated mean pulse-height for a track was defined as the mean value of the lower 70% of the individual pulse-heights and was used as a measure of the ionization. Figure 2 of ref. [5] shows the truncated mean pulse-height versus track momentum for negative particles. Particles are identified in regions where the contamination of other particles is low (5–10%), i.e. kaons to 600 MeV/c and protons (antiprotons) to 1.1 GeV/c.

The resolution in the drift chamber is $230 \mu\text{m}$ (r.m.s.) perpendicular to the wires and 1.5 cm (r.m.s.) along the wires. The resulting momentum resolution for full-length tracks is found to be $\Delta p/p \approx \sqrt{(0.025 p)^2 + (0.01)^2}$ (p in GeV/c), where the first term comes from measurement errors, and the second from multiple scattering in the chamber gas and wires. For dE/dx measurements the truncated mean pulse-height for minimum ionizing tracks has $\sigma_{\text{rms}}/\text{mean} = 11\%$ for > 30 pulse-height measurements.

Two sets of scintillators were placed around the downstream beam pipes to record the luminosity and for use in the trigger. The range of scattering angles covered by these counters was $1.2^\circ < \theta < 6^\circ$. The trigger used was defined by a coincidence between these downstream beam counters. Therefore, all distributions shown are for events with at least one charged particle with $1.2^\circ < \theta < 6^\circ$ to each beam axis. Diffractive events are essentially excluded by this trigger. The cross-section detected by this trigger was 21 mb for both the pp and $p\bar{p}$ runs. The data in this paper were taken at $\sqrt{s} = 53$ GeV.

A total of 172,000 $p\bar{p}$ and a similar number of pp events were reconstructed using the pattern recognition and geometry programs [11] developed for the AFS.

Events were accepted for the analysis if they either had a vertex in a fiducial box around the centre of the interaction diamond or at least one accepted track passing this box. Events that were accepted without having a reconstructed primary vertex had a very low multiplicity of accepted tracks, 90% being one-prong events.

The cuts imposed on the tracks were chosen to ensure that accepted tracks passed close to a reconstructed primary vertex or within the interaction diamond, and that the momentum-measurement error was small.

The acceptance for charged particles in the c.m.s. was found to be uniform in rapidity for $|y| \lesssim 0.8$ and in azimuth in the regions $|\phi| < 80^\circ$ and $110^\circ < \phi < 250^\circ$, i.e. within a total azimuthal range of $\Delta\phi = 300^\circ$. The acceptance was identical within a few per cent for both charges and both polarities of the magnetic field. In $p\bar{p}$ collisions the $\bar{p}$ beam has negative rapidity y .

3. SINGLE-PARTICLE PRODUCTION

The p_T distributions of unidentified charged particles in pp and $p\bar{p}$ collisions are shown in fig. 1, normalized to the trigger cross-sections. The p_T distributions are seen to be identical within errors for p_T up to 5 GeV/c. This confirms our previous comparison [4], which was based on a single-particle trigger in the AFS calorimeter.

Also shown in fig. 1 is the inclusive spectrum at $y = 0$, measured by the British-Scandinavian Collaboration [7]. The shape, as well as the normalization, is seen to agree well with the present measurements for p_T up to 5 GeV/c. This indicates that the non-diffractive events selected in the present study have a p_T distribution similar to the inclusive distribution in the region studied, and that the acceptance for $p_T > 0.2$ GeV/c is close to 100%. For $p_T < 0.2$ GeV/c our acceptance is less than 1.0 (0.8 for $0.1 < p_T < 0.2$ GeV/c and 0.25 for $p_T < 0.1$ GeV/c), as shown by the comparison with the inclusive spectrum, assuming that the agreement between the spectra extends also to this low- p_T region. No correction has been applied for this inefficiency in the following.

The observed charged multiplicity distributions in $|y| < 0.8$, $\Delta\phi = 300^\circ$ are shown in fig. 2 for pp and $p\bar{p}$ collisions. We have not attempted to correct for decays, e.g. K_S^0 . No significant differences are seen. In particular no sign is seen of a high multiplicity annihilation component in the $p\bar{p}$ data when compared with the pp data. The error in the observed multiplicity due to the inefficiency at low p_T is estimated to be around 10%.

Figure 3 shows the ratio of identified charged pions, with $p < 500$ MeV/c, in $p\bar{p}$ and pp collisions versus rapidity. No rapidity dependence of these ratios is observed, within the y -range covered.

The ratios of $p\bar{p}$ to pp production for kaons and protons ($p, \bar{p}$) as a function of p_T and rapidity are shown in figs. 4 and 5. Table 1 gives the overall ratios. They are all in agreement with our previous results at $\sqrt{s} = 63$ GeV [2], but the statistics are now four times larger. The present data do not show any significant p_T dependence of the ratios, although our previous results suggested such a dependence for p and $\bar{p}$ production. We again observe a significant y -dependence of the ratio of $\bar{p}$ and p production, the $\bar{p}(p)$ being

relatively more (less) abundant as y becomes increasingly negative, i.e. toward the $\bar{p}$ fragmentation region. The observation of more $\bar{p}$, even at $y \approx +0.6$ (in the p fragmentation region), in $p\bar{p}$ than in pp demonstrates that the influence of the baryon number of an incident particle can extend across the central region into the backward hemisphere, as discussed in ref. [2]. Our earlier results on these ratios [2] have been interpreted [12] as evidence for “held back” valence quarks, a feature of the dual parton model.

4. RESONANCE PRODUCTION

From mass plots of pairs of charged pions, kaons, protons and antiprotons, signals for ρ , f , K^{*0} , $\bar{K}^{*0}$, ϕ , Λ , and $\bar{\Lambda}$ could be extracted. Invariant masses of $\pi^+\pi^-$, $K^+\pi^-$, K^+K^- , $p\pi^-$, and $\bar{p}\pi^+$ were formed using dE/dx identified kaons, protons, and antiprotons, and calling any other charged particle a pion. For the kaon sample used in $K^+\pi^-$ we estimate the contamination to be 5–10%. To increase the statistics for K^+K^- , $p\pi^-$, and $\bar{p}\pi^+$ the requirements on the kaons, protons, and antiprotons were relaxed. This does increase the contamination of the identified particles, but as the ϕ , Λ , and $\bar{\Lambda}$ resonances are very narrow this does not appreciably affect the signal.

The uncorrelated backgrounds for the $\pi^+\pi^-$, $K^+\pi^-$, $p\pi^-$, and $\bar{p}\pi^+$ pairs were estimated by combining tracks from different events. The background-subtracted spectra for these channels and the raw spectra for K^+K^- are shown in fig. 6 for $p\bar{p}$ collisions. The corresponding spectra for pp collisions are essentially identical, not showing any significant differences. Clear signals of the ρ , K^{*0} , $\bar{K}^{*0}$, ϕ , Λ , and $\bar{\Lambda}$ resonances are seen. A structure is seen in $\pi^+\pi^-$ at 1300 MeV which we interpret as the $f(1270)$. Only those Λ and $\bar{\Lambda}$ which decay close to the primary vertex, so that a secondary vertex is not resolved, appear in the $p\pi$ plots. The lines represent the fits to the sum of the resonance peak and the correlated background, used to extract the amount of resonance production. For the ρ we have used a function of the form $(x - a)^b \exp(-cx)$ to describe the remaining correlated background. The background below the f is described by an exponential. The ρ and f peaks are described by a relativistic Breit-Wigner distribution. The background below K^* is well described by a straight line. A relativistic Breit-Wigner distribution was used to fit the K^* peak. The masses of ρ , f , and K^* were allowed to vary in the fits, whereas the widths were kept fixed. The mass distribution in the ϕ , Λ , and $\bar{\Lambda}$ regions were fit to a straight-line background plus a Gaussian with varying mass and width. Table 2 shows the fitted numbers. The table also includes results of a fit to the K^0 peak, seen in the $\pi^+\pi^-$ mass distribution, which is taken as a measure of our mass resolution (again, only promptly decaying K_S^0 are included). The ratios of ρ , f , K^{*0} , $\bar{K}^{*0}$, ϕ , Λ , and $\bar{\Lambda}$ production in $p\bar{p}/pp$ are within errors all consistent with being equal to 1.0.

Figures 7 and 8 show the ratios of the inclusive cross-sections of ρ , K^{*0} , $\bar{K}^{*0}$, and ϕ , in $p\bar{p}$ and pp collisions, as functions of p_T and rapidity. No clear differences are seen between pp and $p\bar{p}$ collisions, within the errors, i.e. the measured cross-sections from pp collisions can be used to describe the yields in $p\bar{p}$ collisions as well, for the range studied. Thus the annihilation channel is not found to be a significant source of ρ , f , K^{*0} , $\bar{K}^{*0}$, ϕ , Λ , and $\bar{\Lambda}$ in $p\bar{p}$ at the present level of accuracy.

Other measurements at lower energies [6] have found that in pp collisions strange quark fusion contributes significantly to ϕ production. A signature of strange quark fusion should be an associated production of kaons in events with a ϕ . Figure 9 shows the mean number of extra kaons as a function of the invariant mass of K^+K^- , and there is no significant enhancement at the ϕ mass.

5. STOPPING PROTONS

It has been known for some time [8], from the observation that the ratio $p/\bar{p}$ exceeds 1.0 at $y = 0$ in pp collisions at the ISR, that an incident proton can lose all its kinetic energy in particle production (stopped protons). There is also the baryon pair-production process which one would expect to give rise to equal

numbers of p and $\bar{p}$ in the central region. Measurements of single and double baryon production, in pp and $p\bar{p}$ collisions, can shed light on these processes. For example:

- i) when one proton (in pp) stops, is there an enhanced probability that the other also stops?
- ii) Is baryon pair production identical in pp and $p\bar{p}$ collisions?
- iii) If one pair is produced, is the probability of another pair being produced enhanced or depressed?

We have measured the probability in our event sample of observing an identified p or $\bar{p}$, or two such particles, in the central region described above. The acceptance is not simple, owing to identification ranges from dE/dx , but is identical for p and $\bar{p}$, and for pp and $p\bar{p}$ collisions, so comparisons are meaningful.

Table 3 lists the 10 processes measured, where we give the fraction of the event sample for each class. If we consider two origins or classes of central baryons, those from pair production with a probability a , and those from beam stopping—the probability of each beam particle stopping (in our acceptance region) being b —then we can compute the expected probabilities of these processes.

In addition we define:

- d = a possible correlation between pair creation and a stopping proton ($d = 1$ if the processes are independent).
- e = the probability that if a p (or $\bar{p}$) from pair creation is detected, its partner will also be detected, which must be the same in pp and $p\bar{p}$.
- f = a possible correlation between detecting one stopped proton and the other beam particle as a stopped proton (antiproton). No enhancement would give $f = 1$.
- g = a possible correlation between one pair production and a further pair production [$g > 1$ ($g < 1$) if the number of pairs produced has a multiplicity distribution wider (narrower) than a Poisson distribution].

We can now calculate the expected probabilities for the 10 processes, as given by the formulae in table 3. We are assuming that the parameters d , e , f , and g are identical in pp and $p\bar{p}$ collisions.

From the single-particle production processes A, B, C, and D we find, from a least-squares fit to the four processes, $a = (2.36 \pm 0.04) \times 10^{-2}$ and $b = (0.74 \pm 0.03) \times 10^{-2}$, with $\chi^2/\text{d.o.f.} = 2.6/2$. We thus find that a good fit results from assuming a and b to be identical in pp and $p\bar{p}$ collisions, and we shall continue to make that assumption in the following, although we cannot exclude the possibility that one rises and the other falls with the sum, $a + b$, approximately constant. Pair creation is the larger source of central p and $\bar{p}$, a/b being ~ 3 . Using these values for a and b we can determine the four parameters d , e , f , and g by a least-squares fit to the six processes E to J. Processes H and J are identical by C-conjugation; they differ by 2σ which is the major contributor to the $\chi^2/\text{d.o.f.} = 2.8/1$. Our assumption that d , e , f , and g are identical in pp and $p\bar{p}$ collisions is justified by the fit. The values for the fitted parameters are given in table 4. The errors are statistical, plus a possible systematic error resulting from the different absorption probability of p and $\bar{p}$ in the vacuum pipe and detector material.

All four correlation terms are significantly different from 1.0. The parameter $d = 0.16 \pm 0.22$ is lower than 1.0, and thus the observation of a stopping proton decreases the probability of observing a pair creation in this rapidity region. The parameter $e = 0.068^{+0.012}_{-0.004}$ simply means that if we observe a pair-created p or $\bar{p}$, the probability that we observe its partner as an identified $\bar{p}$ or p is $\sim 7\%$, given mainly by acceptance. The parameter $f = 3.0 \pm 1.4$ shows an increased probability of observing a second stopped beam particle, given one. From an estimate of our acceptance for identified p and $\bar{p}$, we find that the cross-section for the process where both beam particles appear in the region $|y| < 0.8$, $0.1 < p_T < 1.2 \text{ GeV}/c$ is $60 \pm 30 \mu\text{b}$ [†]. The parameter $g = 0.31 \pm 0.10$ shows that the observation of a pair creation

[†]) The cross-section for stopping both *nucleons* is presumably a factor four higher, as the nucleon may appear equally as p or n . This is of the same order as the $p\bar{p}$ annihilation cross-section, $\sigma_T(p\bar{p}) - \sigma_T(pp)$, which may be more than a coincidence. We thank M. Jacob for pointing this out.

decreases the probability of observing a second independent pair creation in the same rapidity region, and thus the distribution of multiplicity of pair-creation processes is narrower than Poisson. It should be stressed that these remarks apply to a limited central interval of rapidity.

Finally, we can fit the data on reactions A, B, C, and D to determine a and b as functions of the detected charged multiplicity in the event. This was motivated by the possibility that stopped protons are correlated with high central multiplicity. The results are shown in fig. 10. There is a weak tendency for b to rise faster than linearly in the multiplicity (with an opposite trend for a), but no strong conclusions on this point can be drawn.

6. CONCLUSIONS

The inclusive p_T distributions of charged particles in the central rapidity range $|y| < 0.8$ in pp and $p\bar{p}$ collisions at $\sqrt{s} = 53$ GeV are found to be similar up to $p_T \approx 5$ GeV/c. We observe small differences in the charged kaon and baryon production.

The production of $\rho, f, K^{*0}, \bar{K}^{*0}, \phi, \Lambda$, and $\bar{\Lambda}$ in $p\bar{p}$ interactions has been studied as functions of p_T and rapidity and compared with corresponding pp data. Within errors we do not observe any difference in the production of these particles between pp and $p\bar{p}$ collisions.

Comparisons of single- and double-baryon production have shown several correlation effects: a positive correlation between two "stopping protons", a negative correlation between two pair-creation processes, and a negative correlation between a stopping proton and a pair-creation process.

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Table 1

Ratios of particle production in the central
region in $p\bar{p}$ and pp interaction

Particle type	$n(p\bar{p})/n(pp)$
all ($\pm$)	0.999 ± 0.002
+	0.974 ± 0.003
-	1.026 ± 0.003
$K^+ + K^-$	1.021 ± 0.013
K^-	1.086 ± 0.020
K^+	0.961 ± 0.020
$p + \bar{p}$	1.022 ± 0.016
p	0.84 ± 0.02
$\bar{p}$	1.32 ± 0.03

Table 2

Total ratios of resonance production

Particle	$n_{p\bar{p}}/n_{pp}$	Mass (MeV)		Width (MeV)	
		$p\bar{p}$	pp	$p\bar{p}$	pp
ρ	1.01 ± 0.08	765.6 ± 4.1	766.6 ± 4.8		
K^{*0}	0.84 ± 0.20	886.5 ± 5.2	899.3 ± 5.5		
$\bar{K}^{*0}$	1.05 ± 0.23	896.7 ± 7.1	890.5 ± 5.0		
ϕ	0.86 ± 0.18	1019.9 ± 1.1	1020.9 ± 0.9	13	11
K^0	1.13 ± 0.17	503.3 ± 1.3	502.9 ± 1.4	15	19
Λ	1.19 ± 0.17	1119.8 ± 1.2	1118.9 ± 1.3	20	20
$\bar{\Lambda}$	1.14 ± 0.15	1118.5 ± 1.2	1118.0 ± 1.3	23	22
f	1.01 ± 0.43	1299.0 ± 30.0	1300.0 ± 31.0		

Table 3

Single- and double-baryon production processes measured.
See text for the probability notation.

Symbol	Process	Probability	Measurement
A	$p \rightarrow p \leftarrow p$	$a + 2b$	$(3.80 \pm 0.05) \times 10^{-2}$
B	$p \rightarrow \bar{p} \leftarrow p$	a	$(2.33 \pm 0.04) \times 10^{-2}$
C	$p \rightarrow p \leftarrow \bar{p}$	$a + b$	$(3.15 \pm 0.05) \times 10^{-2}$
D	$p \rightarrow \bar{p} \leftarrow \bar{p}$	$a + b$	$(3.13 \pm 0.05) \times 10^{-2}$
E	$p \rightarrow pp \leftarrow p$	$\frac{1}{2}ga^2 + fb^2 + 2dab$	$(3.10 \pm 0.49) \times 10^{-4}$
F	$p \rightarrow p\bar{p} \leftarrow p$	$\frac{1}{2}ga^2 + ea + 2dab$	$(17.5 \pm 1.2) \times 10^{-4}$
G	$p \rightarrow \bar{p}\bar{p} \leftarrow p$	$\frac{1}{2}ga^2$	$(0.85 \pm 0.26) \times 10^{-4}$
H	$p \rightarrow pp \leftarrow \bar{p}$	$\frac{1}{2}ga^2 + dab$	$(1.58 \pm 0.35) \times 10^{-4}$
I	$p \rightarrow p\bar{p} \leftarrow \bar{p}$	$\frac{1}{2}ga^2 + ea + 2dab + fb^2$	$(18.8 \pm 1.2) \times 10^{-4}$
J	$p \rightarrow \bar{p}\bar{p} \leftarrow \bar{p}$	$\frac{1}{2}ga^2 + dab$	$(0.87 \pm 0.26) \times 10^{-4}$

Table 4

Results of fits to stopping-proton and
pair-creation parameters

Parameter	Fit
a	$(2.36 \pm 0.04) \times 10^{-2}$
b	$(0.74 \pm 0.03) \times 10^{-2}$
d	0.16 ± 0.22
e	$0.068^{+0.012}_{-0.004}$
f	3.0 ± 1.4
g	0.31 ± 0.10

Figure captions

- Fig. 1 The observed p_T distribution of charged particles for $|y| < 0.8$, in pp and $p\bar{p}$ collisions at $\sqrt{s} = 53$ GeV. The line shows the inclusive spectrum $(1/\sigma_{in}) (d\sigma/dydp_T)$ at $y = 0$ from ref. [7].
- Fig. 2 The observed charged particle multiplicity distributions, in $|y| < 0.8$, $\Delta\phi = 300^\circ$, in pp and $p\bar{p}$ collisions at $\sqrt{s} = 53$ GeV.
- Fig. 3 Ratio of $p\bar{p}$ to pp collisions for the production of π^- and π^+ versus rapidity y , for $p_\pi < 500$ MeV/c. The incident $\bar{p}$ has negative y .
- Fig. 4 Ratio of $p\bar{p}$ to pp collisions for the production of identified K^- and K^+ versus rapidity y and p_T .
- Fig. 5 Ratio of $p\bar{p}$ to pp collisions for the production of identified $\bar{p}$ and p versus rapidity y and p_T .
- Fig. 6 Invariant mass distributions for particle pairs in $p\bar{p}$ collisions, after subtracting an uncorrelated background except for K^+K^- .
- a) $\pi^+\pi^-$, inset shows the region of the $f(1270)$. Combinations/25 MeV.
  - b) $K^+\pi^-$, combinations/20 MeV.
  - c) $K^-\pi^+$, combinations/20 MeV.
  - d) K^+K^- , combinations/5 MeV.
  - e) $p\pi^-$, combinations/5 MeV.
  - f) $\bar{p}\pi^+$, combinations/5 MeV.
- Fig. 7 Ratio of $p\bar{p}$ to pp collisions for the production of (a) ρ^0 , (b) K^{*0} , (c) $\bar{K}^{*0}$, (d) ϕ versus p_T , for $|y| \lesssim 1.0$.
- Fig. 8 Ratio of $p\bar{p}$ to pp collisions for the production of (a) ρ^0 , (b) K^{*0} , (c) $\bar{K}^{*0}$, (d) ϕ versus $|y|$ for $p_T \lesssim 1.2$ GeV/c.
- Fig. 9 Average number of additional $K^\pm$ observed in association with a K^+K^- pair, as a function of the mass of that pair, for $p\bar{p}$ and pp collisions.
- Fig. 10 Values of the parameter a (full circles) and b (squares) versus the observed charged multiplicity.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7

Fig. 8

Fig. 9

Fig. 10