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Antiproton-proton and proton-proton elastic scattering at 100 and 200 GeV/*c*

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Antiproton-proton elastic scattering has been measured at 100 GeV/c for $0.5 < -t < 2.5$ (GeV/c)^2 and at 200 GeV/c for $0.9 < -t < 4$ (GeV/c)^2. The data show that the $-t \simeq 1.4$ (GeV/c)^2 dip recently observed at 50 GeV/c persists to higher incident momenta. Proton-proton measurements made at the same beam momenta show similar structure.

In the last two decades there have been many studies of hadron-hadron elastic scattering above the resonance region of a few GeV. A common feature of the cross sections is a narrow peak in the forward direction, which has a particularly simple explanation as diffraction scattering. Several years ago data[1] from the CERN ISR on *pp* elastic scattering at equivalent laboratory momenta of 500–1500 GeV/c showed a dip in the t distribution similar to a diffraction minimum at $-t \simeq 1.4$ (GeV/c)^2, followed by a second maximum and then a slow fall with increasing $-t$.

Subsequent experiments at the CERN ISR (Ref. 2), Fermilab (Refs. 3 and 4), and the CERN SPS (Refs. 5 and 6) established that the $-t \simeq 1.4$ (GeV/c)^2 dip for *pp* scattering develops at around 150 GeV/c from a shoulder at lower momenta, and persists to at least 2000 GeV/c. Studies have been made of the beam-momentum dependence of the position of the dip, its depth, and the height of the secondary maximum. A number of possible theoretical explanations for the dip have been given, and some examples are given in Refs. 7–14. A similar dip at $-t \simeq 1.4$ (GeV/c)^2 is seen in *np* elastic scattering.[15]

In 1980, a dip in $\bar{p}p$ elastic scattering was first reported,[16] occurring also at $-t$ of $\simeq 1.4$ (GeV/c)^2, with 50-GeV/c incident antiprotons. The relation between this dip and structures seen in low-energy $\bar{p}p$ scattering, and the relation between dips in *pp* and $\bar{p}p$ scattering, have been the subject of some study.[17,18]

In view of the interest in this phenomenon, it appeared important to see if the $\bar{p}p$ t distribution shows structure at higher momenta. To do this we have measured $\bar{p}p$ elastic scattering in the range $0.5 < -t < 2.5$ (GeV/c)^2 at 100 GeV/c and in the range $0.9 < -t < 4$ (GeV/c)^2 at 200 GeV/c. We have also measured *pp* elastic scattering at the same two incident momenta.

Details of the experimental technique have been given before,[19] in a report on 200-GeV/c πp elastic scattering results using the same apparatus. Only differences specific to these measurements will be noted here. The apparatus remained the same for the two incident beam momenta, with only magnet currents changed. During negative-beam running, the differential Cherenkov counter in the incident beam was set on antiprotons, which constituted ~3% and ~0.5% of the beam at 100 and 200 GeV/c, respectively. About 13% of the $\bar{p}$'s in the beam were accompanied by an additional pion within the equipment resolving time. The threshold Cherenkov counter in the forward spectrometer provided a veto for those pions which were elastically scattered. Its pressure was set (for almost all of the data reported here) just below the antiproton threshold. Extensive studies of the threshold counter were carried out using protons to determine cuts on the photomultiplier pulse height in order to optimally separate pions and antiprotons. With the cut used, the threshold counter was determined to be 99.2% efficient for detecting pions, leading to a negligible contamination of the antiproton cross section by pions. For proton-proton elastic scattering and for a small subset of the antiproton data, the threshold counter alone was sufficient to reduce the pion contamination of the cross section to negligible levels without use of the beam differential Cherenkov counter.

The analysis and corrections to the data are similar to those previously described.[19] At 200 GeV/c, although the geometrical acceptance extended to $-t$ of 11 $(\mathrm{GeV}/c)^2$, we obtained no events past $-t$ of 4 $(\mathrm{GeV}/c)^2$ for $\bar{p}p$ and $-t$ of 8 $(\mathrm{GeV}/c)^2$ for pp. At 100 GeV/c our data for both reactions extend over the complete geometrical acceptance of $0.5 < -t < 2.5$ $(\mathrm{GeV}/c)^2$.

In order to measure small cross sections in this experiment, data were taken with high ($\sim 10^7$/sec) incident-beam intensities, which gave rise to rate-dependent effects in the beam counters and veto counters. The absolute normalization of the data reported here was obtained by extrapolating to zero beam intensity. We estimate that the systematic uncertainties on the overall normalization of the data presented here are ±10%, except for 200-GeV/c $\bar{p}p$ where they are ±25%.

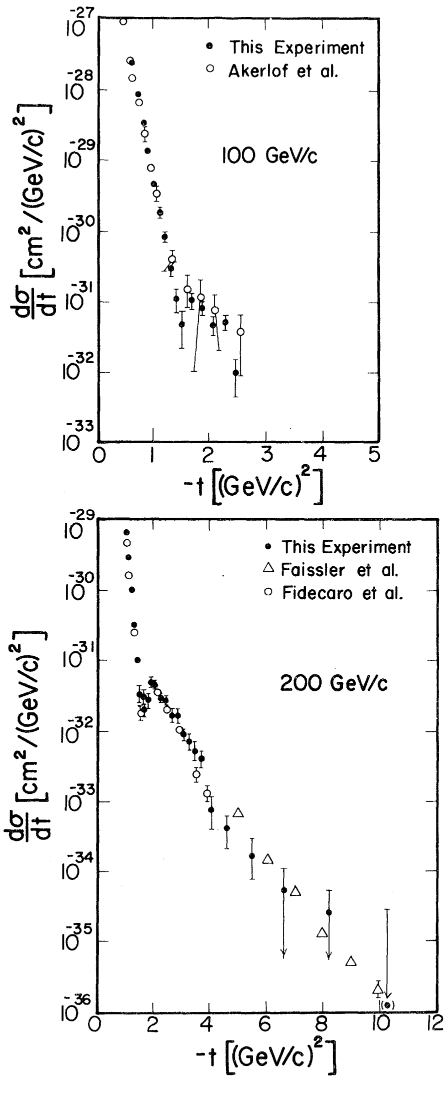

FIG. 1. Data from this experiment on pp elastic scattering at 100 and 200 GeV/c. Also shown are some data (with not all points plotted for clarity) from Refs. 3, 6, and 20.

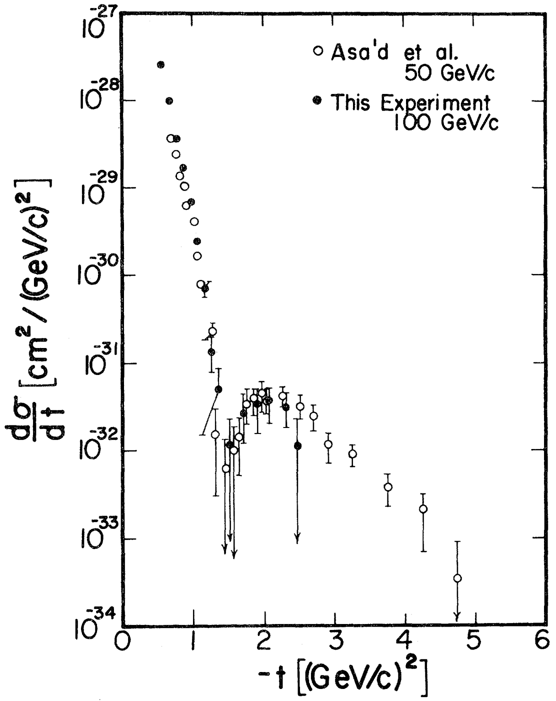

FIG. 2. Results from this experiment on 100-GeV/c $\bar{p}p$ elastic scattering, together with 50-GeV/c data from Ref. 16.

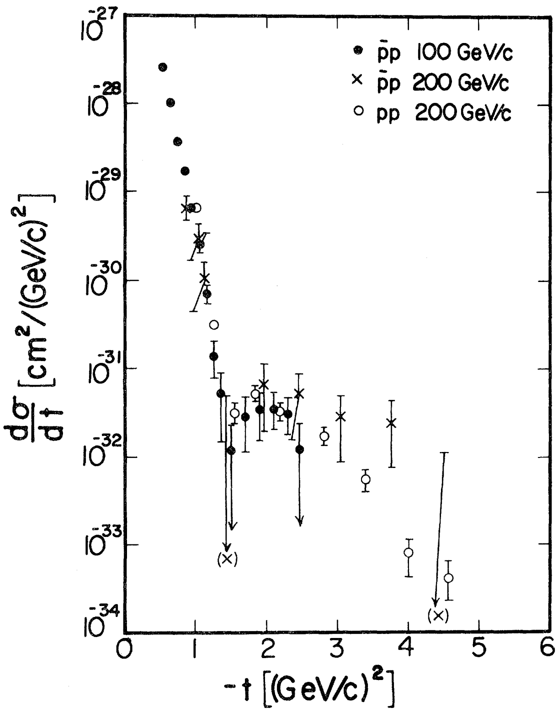

FIG. 3. Results from this experiment on elastic $\bar{p}p$ scattering at 100 and 200 GeV/c, and elastic pp scattering at 200 GeV/c. Not all of the pp points are plotted for clarity. When zero events were observed in a bin, upper limits are shown corresponding to one event.

The proton-proton data are displayed in Fig. 1; agreement with earlier data[3,6,20] is good. We observe clearly the $-t \simeq 1.4$ $(\mathrm{GeV}/c)^2$ dip at 200 GeV/*c*, while at 100 GeV/*c* our data are consistent with a dip at the same value of *t*.

Figure 2 shows our 100-GeV/*c* $\bar{p}p$ data compared with the CERN 50-GeV/*c* data.[16] Our results indicate that the $-t \simeq 1.4$ $(\mathrm{GeV}/c)^2$ dip in this process persists to at least 100 GeV/*c* incident momentum; the 200-GeV/*c* $\bar{p}p$ data, shown in Fig. 3, are of poorer statistical accuracy but are consistent with the same behavior. Figure 2 shows little movement of the dip position with incident momentum, a subject of some interest recently.[17,18] However, expected movements are smaller than could be seen with the available statistics.

Another feature of our data is illustrated in Fig. 3, which compares *pp* and $\bar{p}p$ elastic scattering at 200 GeV/*c* and $\bar{p}p$ at 100 GeV/*c*. We see that, apart from the *t* region in the immediate vicinity of the dip, we do not observe any dependence of the cross section on either beam momentum or particle/antiparticle; the 100-GeV/*c* *pp* cross section (and also the 50-GeV/*c* $\bar{p}p$ cross section), not shown in Fig. 3, are also consistent with this.

In conclusion, we have observed the $-t \simeq 1.4$ $(\mathrm{GeV}/c)^2$ dip in $\bar{p}p$ elastic scattering at a momentum higher than the 50 GeV/*c* where it was previously observed, and have shown that there is little movement of the dip between 50 and 100 GeV/*c*. Further experiments are needed to see if there is some momentum threshold for this phenomenon, as there is in the corresponding *pp* case, or if this dip is related to features seen in low-momentum $\bar{p}p$ elastic scattering. We have also shown that the *pp* and $\bar{p}p$ *t* distributions at 100 and 200 GeV/*c* are all identical within our statistical accuracy.

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