EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH

CERN-EP/84-147
November 5th, 1984

COMPARISON OF $\bar{p}p$ AND pp ELASTIC SCATTERING WITH $0.6 < t < 2.1 \text{ GeV}^2$
AT THE CERN-ISR

S. Erhan, A.M. Smith
CERN, 1211 Geneva 23, Switzerland.

L. Meritet, M. Reyrolle, F. Vazeille
LPC-IN2P3, Universite de Clermont-Ferrand, 63 Aubiere, France.

R. Bonino, A. Castellina, M. Medinnis, P.E. Schlein,
P. Sherwood, S. Vernetto, L. Zawiejski¹, J.G. Zweizig
University of California^{*)}, Los Angeles, California 90024, USA.

J. Alitti, B. Bloch-Devaux, J.B. Cheze,
J. Mallet, A. Montag, J. Zsembery
Centre d'Etudes Nucleaires-Saclay, 91191 Gif-sur-Yvette, France.

Geneva, October 29, 1984

Abstract: $\bar{p}p$ and pp elastic scattering differential cross sections are presented for momentum transfer $0.6 < t < 2.1 \text{ GeV}^2$ and $\sqrt{s} = 53 \text{ GeV}$. Measurements were made in the same apparatus at the CERN Intersecting Storage Rings. The $\bar{p}p$ and pp results are in statistical agreement with one another over the entire t range, although the point at $t=1.32 \text{ GeV}^2$ is 1.5σ above the pp data. The $\bar{p}p$ points appear to have the same shape as the predictions of Donnachie and Landshoff but are significantly lower in magnitude for $0.9 < t < 1.5 \text{ GeV}^2$.

Submitted to Physics Letters

^{*)} Supported by U.S. National Science Foundation grant PHY 79-24766

¹ visitor from Institute of Nuclear Physics, Krakow, Poland

The absence of a dip near t of 1.3 GeV^2 in $\bar{p}p$ elastic scattering at $\sqrt{s}=540 \text{ GeV}$ [1], has led to speculation about the reasons for this high energy behavior and, as a consequence, about how $\bar{p}p$ and pp elastic scattering may compare at ISR energies. Donnachie and Landshoff [2] propose that in $\bar{p}p$ scattering the dip may be absent due to the fact that the three gluon exchange term has opposite sign in pp and $\bar{p}p$ scattering, and that the dip seen at low $\bar{p}p$ energies (which comes from a different source) will have disappeared at ISR energies. Islam et al. [3] make entirely different predictions (based on a valence core model) in which the prominent dip in $\bar{p}p$ scattering still exists at ISR energies but at a lower value of t .

We have measured both $\bar{p}p$ and pp elastic scattering at $\sqrt{s} = 53 \text{ GeV}$, in the t range $0.6\text{--}2.1 \text{ GeV}^2$ with the same apparatus. The data described in this letter were taken during the last period of $\bar{p}p$ running at the ISR in November 1983. The integrated luminosities during the relatively short elastic runs were 2.41 nb^{-1} for the $\bar{p}p$ data and 41.25 nb^{-1} for the pp calibration data. The pp run immediately followed the $\bar{p}p$ run.

The apparatus used for the acquisition of these data consisted of a magnetic spectrometer positioned around the outgoing beam pipe in ring 2 of the ISR, a set of veto counters covering the central region, and a set of scintillation counters around the outgoing beam pipe in ring 1.

The spectrometer [4] measured the momentum vector of the scattered $\bar{p}$ (or a scattered p in the case of pp scattering). The acceptance aperture was $0 < |\theta_x| < 150 \text{ mrad}$ in the horizontal direction and $23 < |\theta_y| < 150 \text{ mrad}$ in the vertical direction. The momentum resolution was $\delta p/p = .0023p$ and the angular resolution was 0.19 mrad in each view. The spectrometer was divided into two identical halves - one positioned above the beam pipe, and the other below - allowing us to make two independent measurements of elastic scattering. Consistency between these two measurements provides a valuable check of our results. Since the spectrometer was in the $\bar{p}$ arm for the $\bar{p}p$ run, the magnetic field was reversed during this run to insure that the spectrometer acceptance was the same for both the pp and $\bar{p}p$ data.

The central region veto counters were used to suppress the bulk of the inelastic cross-section. They consist of a barrel hodoscope surrounding the interaction region and a wall of lead-scintillator sandwich veto counters in each outgoing arm.

The scintillation counter system in arm-1 was used to reject events in which the arm-1 proton was diffractively excited. This system consisted of two scintillators, F1, used for pulse height measurement, followed by finger hodoscopes (for recoil proton detection) situated above and below the beam pipe 3.5 meters downstream of the interaction region. As shown in Fig. 1, these

hodoscopes consisted of two layers of 2 centimeter wide by 30 centimeter long horizontal slats. The slats in the back layer were offset by 1 centimeter vertically, thus providing 10 bins of 1 centimeter width. These counters are used offline to select events which satisfy a collinearity condition (in the vertical plane) described below.

The trigger demanded that at least one track traverse the spectrometer (using wire chamber multiplicity information ^[4]), that there be at least one hit in the arm-1 recoil proton hodoscope diagonally opposite the spectrometer-half containing the track and that no barrel counter be struck.

The raw data were passed through our reconstruction program and events with one track found in the spectrometer and no veto counters struck were accepted for further study. The events were further required to have hit(s) in the recoil-proton hodoscope and to have an F1 counter pulse height in the single particle peak. These events are predominantly elastic events and single diffractive events (in which the recoil proton has entered the spectrometer). This can be seen from Figs. 2(a-d) which show the single particle momentum distributions of the selected events from the pp and $\bar{p}p$ data samples separately for t below and above 1.2 GeV^2 . The prominent peaks centered at the beam momentum consist of these elastic and single diffractive events.

The elastic events are further isolated with the aid of the recoil proton hodoscopes described above. Fig. 3 shows distributions of the collinearity variable, ΔY , which is the vertical separation between the center of the struck hodoscope bin and the projected recoil proton position on the counter plane. The distributions are shown for various t bins for both the $\bar{p}p$ and pp reactions. In each part of Fig. 3, there is a clear elastic signal peak centered near $\Delta Y=0$, indicating the presence of the recoil proton collinear with the track measured in the spectrometer. Events selected in the signal regions of Figs. 3 are seen to have improved signal/background ratios in the shaded areas of Figs. 2.

Each step of the analysis and selection procedure described above was modeled with a Monte Carlo program independently for the $\bar{p}p$ and pp runs. The efficiencies of the chambers and each of the trigger counters were included in the Monte Carlo generation. The generated events were processed through the same analysis and selection routines used for the real data. The resulting Monte Carlo events matched the data in all distributions tested, including the interaction position as measured by extrapolating the spectrometer track to the beam plane, the distribution of the tracks in the plane of the first chamber, and the collinearity variable described above.

The numbers of elastic events are determined by fitting the ΔY histograms in Figs. 3 to a function which is a sum of signal and background terms. The

signal shapes are given by the Monte Carlo events generated independently for each t -bin and a quadratic polynomial is used to describe the background. The results of these fits are shown as solid curves in Figs. 3.

The corrected¹ cross sections appear in Fig. 4 and in Table 1. The integral cross sections for the t -range 0.6 - 2.1 GeV^2 are 8.84 ± 0.19 and 9.33 ± 0.09 μb for $\bar{p}p$ and pp , respectively, with a difference of 0.50 μb (± 0.20 statistical, ± 0.50 systematic). The $\bar{p}p$ and pp measurements are seen to be compatible both globally and at individual t points, (the $\bar{p}p$ point at $t=1.32$ GeV^2 is 1.5σ above the pp data).

The lower curve in Fig. 4 is a fit by Donnachie and Landshoff^[2] to previous ISR measurements of pp elastic scattering^[5] and is an excellent summary of those measurements. In the following discussion, we therefore use this curve to represent the earlier data^[5]. The integral under the curve is 8.47 μb in the same t -range as our data, corresponding to a 10% normalization difference between curve and data. This difference is consistent with our expected systematic cross section uncertainty and therefore, to facilitate comparison, we have normalized the curve to our pp data in Fig. 4. Our pp results are seen to agree reasonably well with this curve, although for larger t there may be a small systematic difference² in the t -scale between this experiment and that of Ref. [5].

The upper curve in Fig. 4 is the prediction of Ref. [2] for $\bar{p}p$ scattering (also scaled up by +10%). Although the absence of a dip in the prediction agrees qualitatively with our data, in the region $0.9 < t < 1.5$ GeV^2 the data points are significantly below the curve and are statistically inconsistent with it. Islam et al.^[3], on the other hand, predict a dip in $\bar{p}p$ elastic scattering at a lower t -value than in pp (≈ 1.0 GeV^2). This prediction (not shown in Fig. 4) disagrees substantially with our data for $t > 0.8$ GeV^2 .

We thank A. Donnachie and P. Landshoff for communicating their results to us prior to publication and for several useful discussions. These results were made possible by the magnificent teamwork of the Antiproton Accumulator Group and the ISR and PS Operations Groups in the complex operations that resulted in the stored antiproton beams in the ISR. We are grateful to them and the ISR Experimental Support Group for their efforts.

¹ Corrections not included in the Monte Carlo generation, but added explicitly, include accidental vetos, nuclear absorption, F1 pulse height cuts, and losses in the trigger multiplicity logic.

² It is worth pointing out, however, that there can be no relative t -scale uncertainty between the $\bar{p}p$ and pp data in this paper.

Table 1: pp and $\bar{p}p$ elastic cross sections (in $\mu\text{b}/\text{GeV}^2$)

t Bin	$\langle t \rangle$	pp	$\bar{p}p$
0.6-0.7	0.64	61.33 ± 0.73	57.07 ± 1.44
0.7-0.8	0.74	20.76 ± 0.38	20.38 ± 0.98
0.8-0.9	0.84	7.62 ± 0.18	7.33 ± 0.54
0.9-1.0	0.94	2.35 ± 0.08	2.16 ± 0.28
1.0-1.1	1.04	0.647 ± 0.045	---
1.1-1.2	1.14	0.133 ± 0.032	---
1.0-1.2	1.08	$(0.381 \pm 0.031)^1$	0.393 ± 0.102
1.2-1.3	1.24	0.040 ± 0.020	---
1.3-1.4	1.35	0.046 ± 0.015	---
1.4-1.5	1.45	0.055 ± 0.014	---
1.2-1.5	1.32	(0.052 ± 0.009)	0.103 ± 0.036
1.5-1.6	1.55	0.046 ± 0.014	---
1.6-1.7	1.65	0.072 ± 0.014	---
1.7-1.8	1.75	0.073 ± 0.014	---
1.5-1.8	1.64	(0.060 ± 0.007)	0.058 ± 0.031
1.8-1.9	1.85	0.065 ± 0.012	---
1.9-2.0	1.95	0.063 ± 0.011	---
2.0-2.1	2.05	0.037 ± 0.011	---
1.8-2.1	1.94	(0.056 ± 0.007)	0.050 ± 0.026

¹⁾ the bracketed cross sections (not plotted in Fig. 4) are obtained from fits to the summed data on the preceding lines.

References

- [1] M. Bozzo et al. (UA4 collaboration): Contribution to the Europhysics Conference on High Energy Physics, Brighton (July 1983) and Phys. Lett. (in press - 1984)
- [2] A. Donnachie and P. V. Landshoff, Nucl. Phys. B231 (1983) 189; Phys Lett. B123 (1983) 345.
- [3] M. M. Islam, T. Fearnley and J. P. Guillaud, CERN-EP/83-96 (preprint -1983)
- [4] P. Chauvat et al., The Performance of a 16,000 Wire Mini Drift MWPC System; CERN-EP/82-198; Proceedings of the 1983 DPF Workshop on Collider Detectors (LBL-15973), p. 81, and contribution to XXI International Conference on High Energy Physics; Paris, July, 1982
- [5] E. Nagy et al., Nucl. Phys. B150 (1979) 221.

FIGURE CAPTIONS

- 1. Illustration of a recoil-proton scintillation counter hodoscope positioned 3.5 m from the interaction center.
- 2. Momentum of single track pp events with (a) $t < 1.2 \text{ GeV}^2$, (b) $t > 1.2 \text{ GeV}^2$. (c-d) are the same, but for the $\bar{p}$'s in the $\bar{p}p$ sample. In each case the shaded area shows those events which have a collinear track in the opposite arm ($-0.9 < \Delta Y < 0.6 \text{ cm}$ in Figs. 3).
- 3. Distributions in recoil-proton collinearity variable (ΔY), as described in the text, for: (a-h) $\bar{p}p$ data for each of the t -bins shown in Table 1; (i-p) pp data for the same t -bins used in (a-h).
- 4. Elastic $d\sigma/dt$ for $\bar{p}p$ and pp interactions. The curves (upper for $\bar{p}p$, lower for pp) are from Ref [2]. The curves are scaled upward by +10%, as described in the text, so that the pp curve is normalized to the data.

FIGURE 1

FIGURE 2

FIGURE 3