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Small t Physics at the TEVATRON Collider*

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Presented by W.F. Baker

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The first physics run of the superconducting Tevatron Collider at Fermilab ended this morning. I will present a status report on the progress of the small angle elastic scattering and total cross section experiment, E710. The goals of this experiment are to measure the total proton-antiproton cross section from $\sqrt{s}$ = 300 to 2000 GeV, the slope of the diffraction peak and ρ, the ratio of the real to imaginary part of the forward scattering amplitude, at these energies.

INSTALLATION

The layout of the experiment is shown schematically in Figure I. It is located in the EO straight section diametrically opposite BO where the Collider Detector Facility is situated. The detectors for measuring small angle scattering are located in four pairs of "Roman Pots"; one pair at each end of the straight section and two more buried in the magnet lattice of the Collider. The latter provide good angle and momentum resolution for the detection of very small angle elastic scattering. The entire experiment is symmetric about the interaction point except for the locations of the outer pots. Focusing by the accelerator quadrupole magnets makes the effective distances to these outer pots about 80 m.

Elastic scattering can be measured from the coulomb region out to approximately $-t = 1\ (GeV/c)^2$ at $\sqrt{s} = 2000$ GeV.

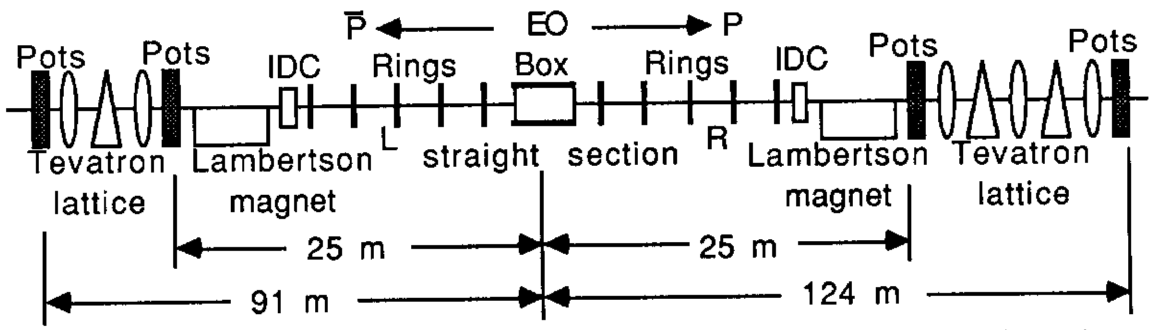

Figure 1. Arrangement of the detectors and Tevatron components for the Elastic Scattering and Total Cross Section Experiment, E710

In each pair of pots one pot is located above and one below the circulating beams, and they can be moved remotely into the Tevatron vacuum chamber. Each pot contains three scintillation counters and a drift chamber. Two of the counters are used in triggering the readout of the drift chambers and the third is used to calibrate the chambers. Each drift chamber has four sense wires to give four measurements of the vertical scattering angle from the drift times and four horizontal coordinates by charge division. Typical accuracies achieved are about ±0.1 mm and ±0.6 mm respectively for the two coordinates. The pots are filled with an argon-ethane mixture with ethanol added. Figure 2 shows the construction of these detectors which are described in detail in

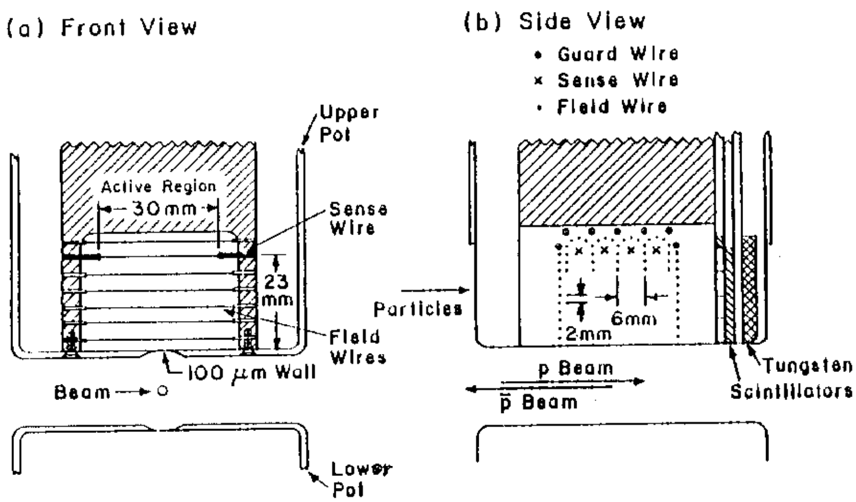

Figure 2. Front and side views of a drift chamber mounted in its pot, which is the container for the chamber gas.

our earlier publication.[1] A photograph is given in Figure 3, and Figure 4 shows a typical installation.

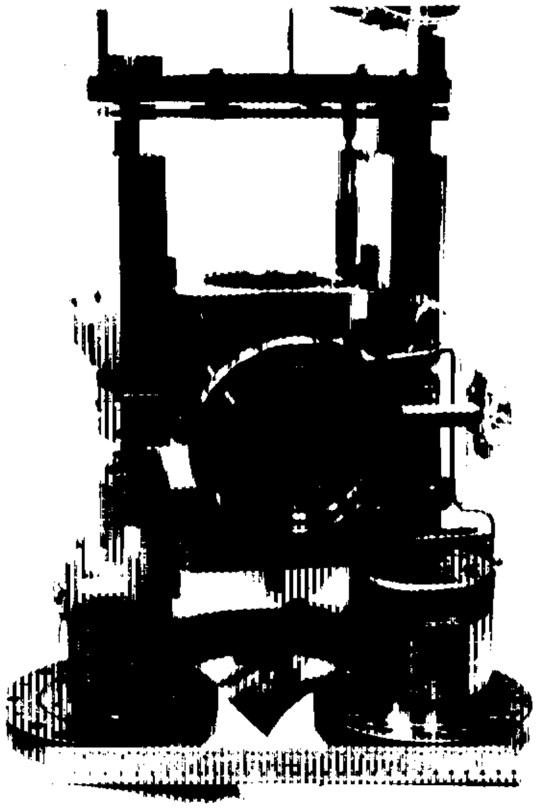

Figure 3. A drift chamber, a pot and the mounting and movement structure. All are viewed approximately in the beam direction. Note the groove machined into the bottom of the pot to enable it to get closer to the beams and the thin window through which the scattered particles pass.

Located around the interaction point are 48 scintillation counters which cover the rapidity interval from - 6.5 to + 6.5. At the center is an open ended box of scintillators 183 cm in length; outboard of this on each side are five annular counters spaced along and sorrounding the beam pipe. These counters are used to measure the total inelastic counting rate which when combined with an extrapolation of the differential elastic counting rate, dN/dt, to t = 0 yields the total cross section in a luminosity-independent manner. This makes use of the optical theorem:

$$\sigma_{TOT}(1 + \rho^2) = \frac{16\pi \left.\frac{dN}{dt}\right|_{t=0}}{N_{TOT}} \qquad (1)$$

in which ρ^2 is predicted to be only ~ 2 % and where N_{TOT} is the total (elastic plus inelastic) rate.

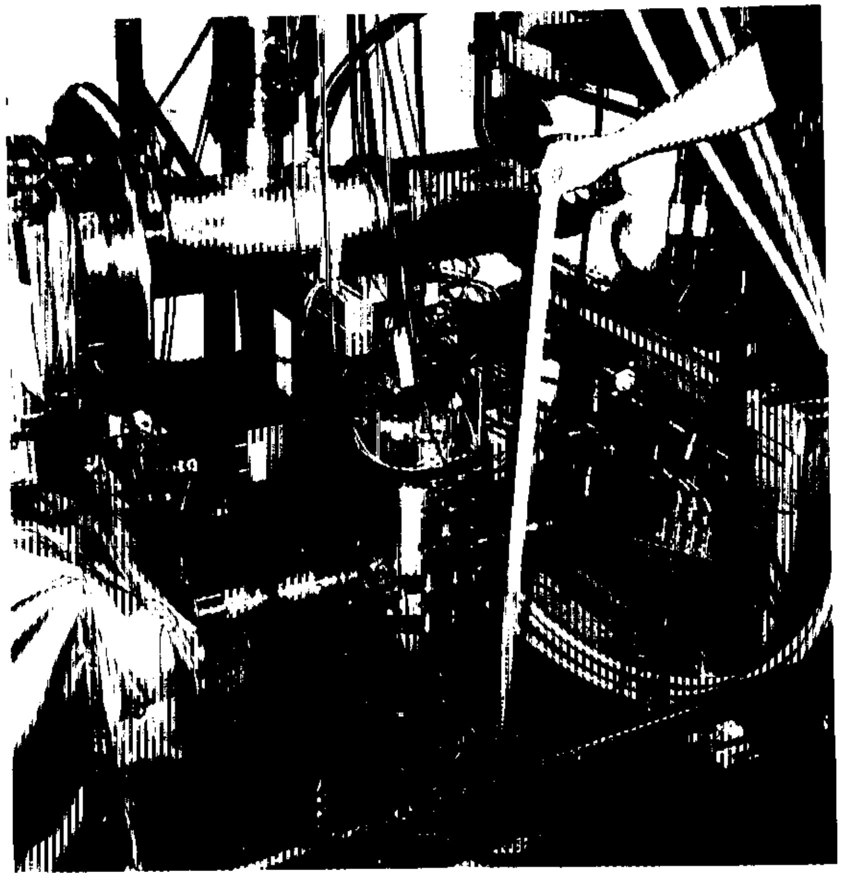

Figure 4. A set of pots installed in the Tevatron at the end of the EO straight section. The upper vacuum pipe is the Main Ring, and to the left are the ends of the Lambertson magnets which are used in transferring the beams from the Main Ring into the Tevatron.

EO is the straight section in which protons and antiprotons are transferred from the Main Ring into the Tevatron and is therefore somewhat congested with accelerator components. Figure 5 shows the installation of one of the ring counters in this environment.

Just after the last ring counter, Figure 1, are located the inelastic drift chambers which form telescopes that track back to determine if an event was a beam-beam interaction, a beam gas interaction or scraping of the beam on some part of the accelerator.

OPERATION

Collider luminosity increased during the run, and towards the end was on the order of 10^{27} $cm^{-2}sec^{-1}$ at EO. This is down a factor of 80 from the luminosity at BO (CDF) due to the smaller value of beta there. All data were taken at a total energy of 1800 GeV although there was a brief run at 630 GeV with low luminosity. We were able to insert the detectors in the outer pots to within 5 mm of the center of the beams to measure scattering angles down to 70 microradians.

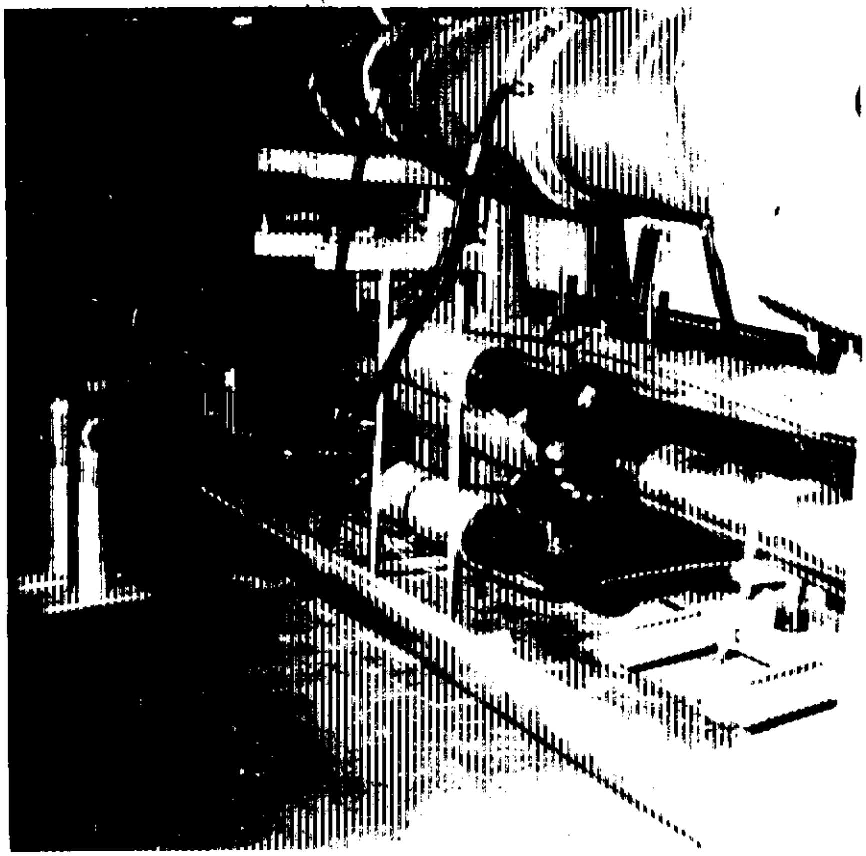

Figure 5. A ring counter consisting of four seperate counters for detecting inelastic interactions surrounding the Tevatron vacuum pipe. The vacuum pipe just above the counter is the antiproton injection line. Above that, wrapped in insulation for bake-out, is the injection line for protons.

Various combinations of coincidences among the counters in the pots and the inelastic counters were used to trigger the read out of the drift chambers. It was also possible to trigger on signals from the drift chambers directly. Emphasis was placed on coincidences between the outer pots. Other triggers included left-right inelastic counter coincidences to measure the inelastic rate. Each counter was strobed by a Tevatron timing signal synchronized to the beam passage and latched in a register, analyzed in an ADC and timed in a TDC. This information was used both on-line and off-line to interpret the triggered events.

Between the inelastic drift chambers and the inner set of pots are situated the Lambertson magnets required for injection. Once injected the circulating beam passes through a hole in the return leg of the magnet, its orbit passing close to the notch as indicated in Figure 6. Beam scraping can occur at these locations and contributes to background events. It also results in a portion of the detectors in the pots being shadowed. These effects were particularly serious for the inner pots. A horizontal displacement "bump" of up to 12 mm was put into the accelerator orbit to move it away from the notch. In preparation for the next run the Lambertson magnets are being motorized so that they can be moved aside once store has been achieved.

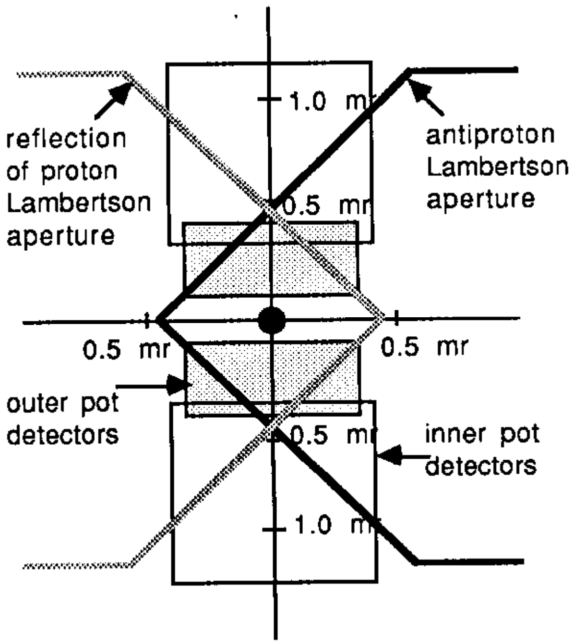

Figure 6. Angles subtended at the point of scattering by Lambertson magnet apertures and pot detectors. Looking in the direction of antiproton travel shows the antiproton injection magnet and the kinematical reflection of the proton injection magnet.

Tests were made to determine the effects of scraping away the beam halo. These yielded a significant reduction in background rates and also showed that the halo grew back at a rate of about 5 microns per minute.

As the photographs show, the Main Ring Accelerator is only 65 cm above the Tevatron. During the Collider store protons are being accelerated in it at rates up to every 2.4 seconds to 120 GeV to produce antiprotons. The detectors were gated off during this time. It was also necessary to gate them off during run-down of the Main Ring field ramp as this induced bias voltages in signal cables from some of the detectors. As a result the detectors were sensitive only 17% of the time.

PRELIMINARY RESULTS

In a typical run once a store was achieved the pots were run in until the counters in them started to see beam. They were then backed out to a position such that the pots in a pair were equidistant from the beams and such that conjugate pots on either side of the interaction region covered the same scattering angles. Data were then recorded for several hours and monitored by on-line displays. Figure 7 is an on-line scatter plot of the vertical coordinates in pot 2 (outer, lower, antiproton) and pot 7 (outer, upper, proton). Coordinate values increase towards the beam which is off the figure to the upper right. A software cut has rejected events with hits in counters other than in the pots involved. As expected for colinear elastic scattering, events are clustered along a diagonal; -t increases to the lower left. Accidental events involving a halo particle appear at large y values off the diagonal.

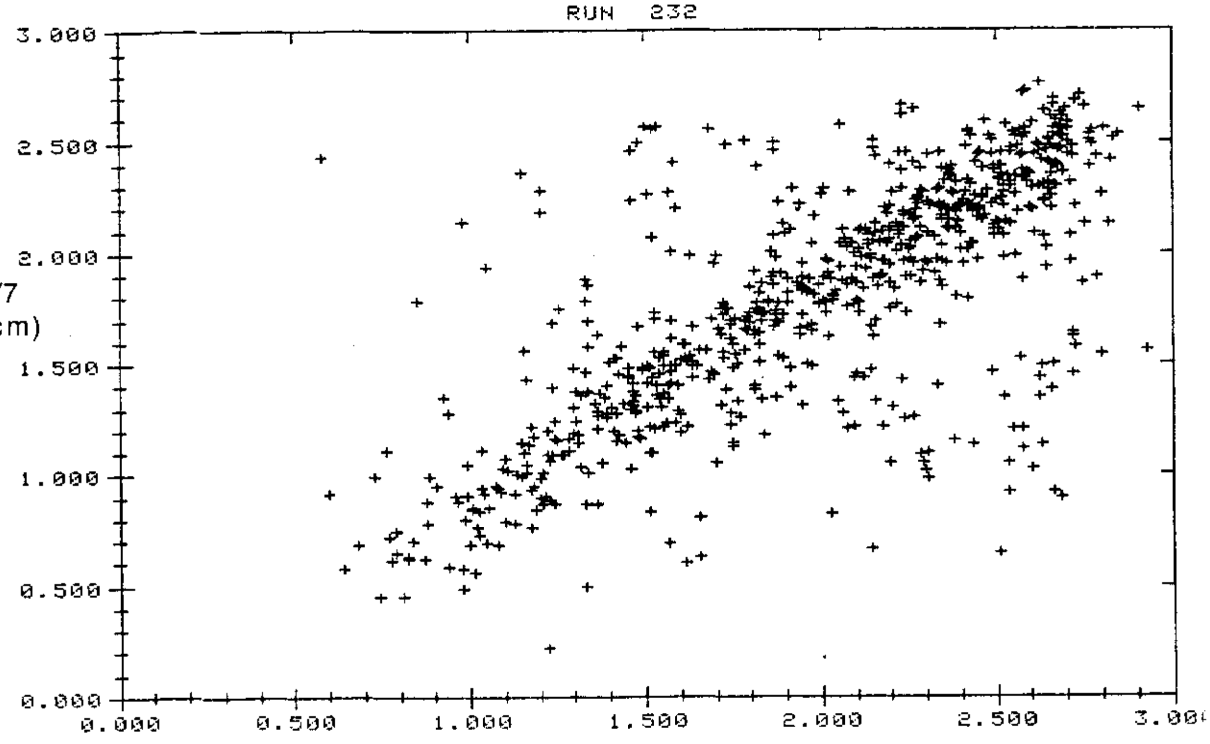

Figure 7. Vertical coordinates in conjugate outer pots for events having no hits in counters other than in the pots involved.

A similar plot of the horizontal coordinates shows a less pronounced diagonal due to the less accurate charge division resolution.

Off-line analysis of the data is currently underway. An example of preliminary results for elastic scattering from one run is given in Figure 8. The exponential slope, b, obtained for the differential cross section shown is 16 ± ~ 2 $(GeV/c)^{-2}$, consistent with extrapolations from previous experiments. This figure represents 1002 events.

Improvements are being made in preparation for the next run. Although no radiation damage was seen in the scintillator used, thicker trigger counters are being made, the drift chambers are being rewired, a more powerful on-line computer is being added and as noted above the Lambertson magnets are being made moveable.

ACKNOWLEDGEMENTS

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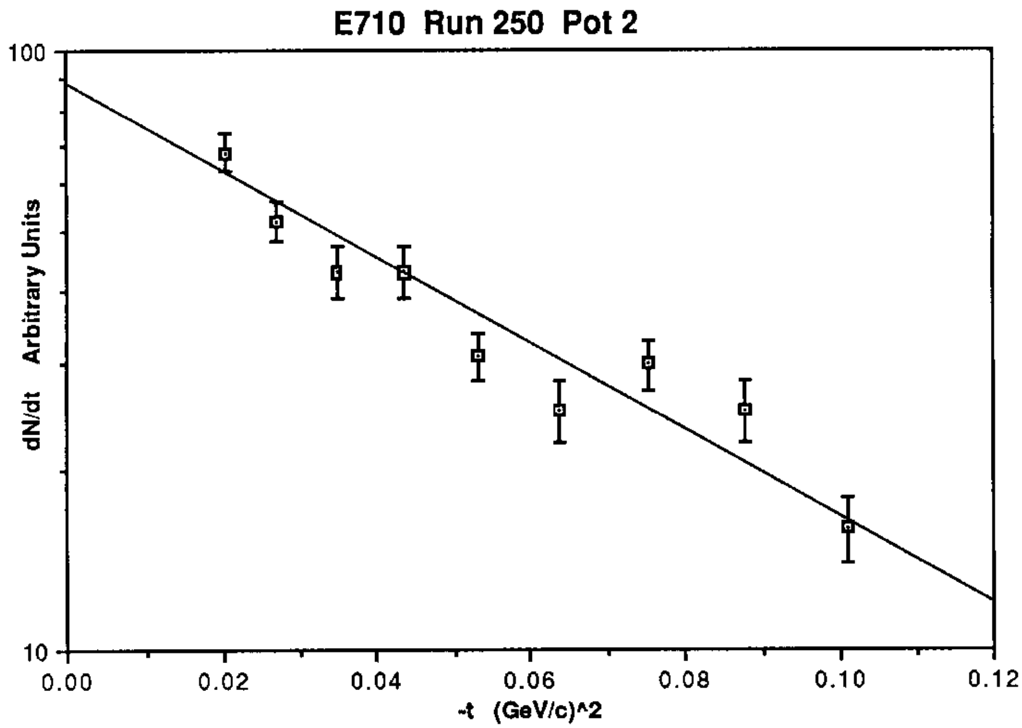

Figure 8. Preliminary differential elastic cross section for proton-antiproton scattering at 1.8 TeV.

Reference

(1) N. Amos et al., Nucl. Instr. and Meth. in Phys. Res. A252, 263 (1986).