FERMILAB-Conf-91/227

Measurement of ρ, the Ratio of the Real to Imaginary Part of the $\bar{p}p$ Forward Elastic Scattering Amplitude, at $\sqrt{s}$ = 1.8 TeV

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August 1991

* Presented at *Particles and Fields '91*, University of Vancouver, Vancouver, British Columbia, Canada, August 18-22, 1991.

MEASUREMENT OF ρ, THE RATIO OF THE REAL TO IMAGINARY PART OF THE $\bar{p}p$ FORWARD ELASTIC SCATTERING AMPLITUDE, AT $\sqrt{s}$ = 1.8 TEV

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ABSTRACT

We have measured ρ, the ratio of the real to the imaginary part of the $\bar{p}p$ forward elastic scattering amplitude, at $\sqrt{s}$ = 1.8 TeV. Our result, $\rho = 0.140 \pm 0.069$, is consistent with the expected value, and thus no new physics is required.

1. Introduction

Fits to $\bar{p}p$ and pp measurements of ρ and the total cross section σ_T available up to ISR energies have been used, together with dispersion relations, to predict values of ρ and σ_T at SPS and Tevatron Collider energies.[1,2] The predictions for total cross sections were in agreement with measured values when they became available. However the SPS UA4 measurement[3] at $\sqrt{s}$ = 546 GeV of $\rho = 0.24 \pm 0.04$, was ~ 2.5 standard deviations from the expected value of ~ 0.14. To explain a value of 0.24, some new physics is required, although some models were later ruled out by our subsequent measurement[4] of σ_T at $\sqrt{s}$ = 1.8 TeV.

2. Experimental Method

Our apparatus and event selection have been described in earlier publications[4-7]. Because our drift chamber horizontal (x) coordinate readouts (based on charge division) were known with substantially less accuracy than the vertical (y) coordinate readouts, we integrated over x and only used the y coordinate in our analysis. In order to determine ρ, elastic scattering was measured down to $|t| \sim 0.001(\text{GeV/c})^2$, where the maximum interference between coulomb and nuclear scattering occurs.

We use the following expression for the observed elastic differential cross section.

$$\frac{1}{L}\frac{dN_{el}}{dt} = \frac{d\sigma}{dt} = \frac{4\pi\alpha^2(\hbar c)^2 G^4(t)}{|t|^2} + \frac{\alpha(\rho - \alpha\phi)\sigma_T G^2(t)}{|t|}e^{-B|t|/2} + \frac{\sigma_T^2(1+\rho^2)}{16\pi(\hbar c)^2}e^{-B|t|} \quad (1)$$

The three terms are due to, respectively, coulomb scattering, coulomb-nuclear interference, and nuclear scattering. L is the integrated accelerator luminosity; α is the fine structure constant, ϕ is the known relative coulomb-nuclear phase; G(t) is the known nucleon electromagnetic form factor. We also use the following two equations:

$$\sigma_T^2 = \frac{1}{L}\frac{16\pi(\hbar c)^2}{(1+\rho^2)}\frac{dN_{el}^n}{dt}|t=o \quad ; \quad \sigma_T = \frac{1}{L}(N_{el}^n + N_{inel}) \qquad (2,3)$$

N_{el}^n is the total number of nuclear elastic events, obtained from the observed elastic distribution in the t region where nuclear scattering dominates, and extrapolated to t = 0 and t = ∞ using the form exp(-B|t|).

$\frac{dN_{el}^n}{dt}|t=o$ is the observed differential number of nuclear elastic events extrapolated to t = 0 using the same form. N_{inel} is the total number of inelastic events, obtained as described earlier.[4] We use our elastic data and N_{inel}, together with Eqs. (1), (2) and (3), to obtain simultaneously σ_T, B and ρ. As explained earlier, this procedure was modified in practice, although not in principle, because instead of using measurements of $\frac{dN_{el}}{dt}$ as input, we used $\frac{dN_{el}}{dy}$ where y is the vertical distance from the beam center, and where each y bin covers a range of t.

3. Results and Conclusions

The result obtained from the simultaneous fit to our data described above was

$$\rho = 0.140 \pm 0.069; B = 16.99 \pm 0.47 \ (\text{GeV/c})^{-2}; \ \sigma_T = 72.8 \pm 3.1 \text{ mb}$$

The new values of B and σ_T given above are consistent with our earlier published results.

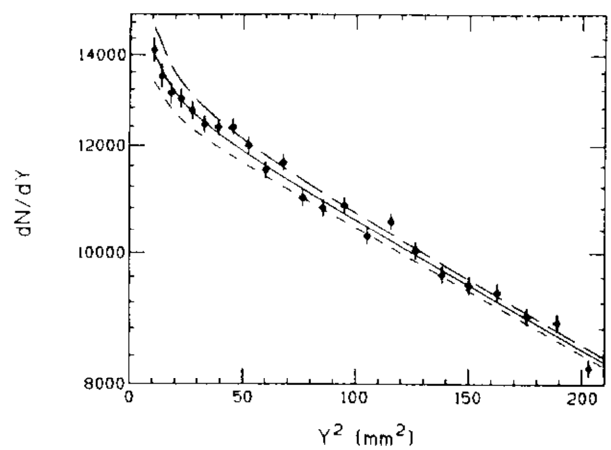

Fig. 1

We show in Fig. 1 our elastic data as a function y^2, together with our fit, for only the small y^2 region. Also shown are two curves (long dashed for $\rho = 0.28$ and short dashed for $\rho = 0$) illustrating the effect of changing ρ, but keeping B and $\sigma_T(1+\rho^2)$ fixed. [Note that B and $\sigma_T\ (1+\rho^2)$ are essentially determined from the larger y data].

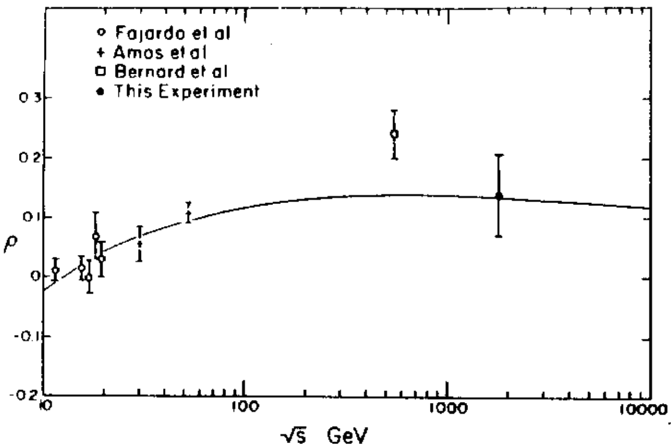

Fig. 2

Our result for ρ is shown in Fig. 2, together with results at lower energies[3,8,9], and a curve[10] showing the dispersion relation prediction based on existing data except for the ρ value at $\sqrt{s} = 546$ GeV. It can be seen that our value of ρ is consistent with that expected, and thus our result does not require the addition of any new physics.

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This work was supported by the U.S. Department of Energy, the U.S. National Science Foundation, the Italian Ministero Pubblica Istruzione and the North Atlantic Treaty Organization.

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