that all Υ''' resonances decay into a $B\bar{B}$ pair, we obtain a branching ratio for $B \to (D, D^*)e\nu$ of $(13.6 \pm 2.5)\%$. For the $b \to u$ case, 90% of the spectrum is above 1 GeV and no extra contribution is expected, giving the same branching ratio. We estimate that our Monte Carlo modeling of the electron acceptance introduces a systematic uncertainty on the value of the branching ratio of the order of 20% of its value.

We also use our results to obtain upper limits for the decay $B \to e\nu X_u$ induced by a $b \to u$ coupling. For this analysis we include electrons whose energy is greater than 800 MeV. The resultant upper limit depends on the assumed $\langle M_X \rangle$ value. We obtain for the ratio of branching fractions $B(B \to e\nu X_u)/B(B \to e\nu D, D^*) \leq 0.23$ for $X_u = 50\%$ (π, η) and $50\% (\rho, \omega)$, ≤ 0.32 for $M_{X_u} = 1$ GeV, and < 1.5 for $M_{X_u} = 1.8$ GeV, at 90% confidence level. In all cases the best fit is obtained for $B(B \to e\nu X_u) = 0$, with the fit for $B \to e\nu D, D^*$ having a value of $\chi^2/\text{D.F.} = 0.96$.

In conclusion, we have detected a strong enhancement of electron yield in multihadron events at the $4S$ peak giving evidence for the weak decay of a new quark, b. The semileptonic branching ratio of $B \to Xe\nu$ has been determined and the observed energy spectrum of the electrons favors $b \to ce\nu$.

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Measurement of Deuteron-Deuteron Elastic Scattering at 5.75 GeV/*c*

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The elastic differential cross section of 5.75-GeV/c deuterons scattered from deuterium has been measured over a range of $0.125 < -t < 2.0$ (GeV/c)^2. The result shows a narrow interference minimum at $-t = 0.18$ (GeV/c)^2, but does not have a simple exponential behavior in the double-scattering region. The latter effect is attributed to constructive interference between the two double-scattering amplitudes, which have different t dependences. The results are compared to existing data and to a Glauber-model calculation.

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The multiple-diffraction model of Glauber[1] successfully explains many of the major features of elastic hadron-nucleus scattering. The model treats the scattering process as a sequence of individual collisions between the projectile and the nucleons of the target, and its predictions depend on both the nucleon-nucleon scattering amplitudes and the nuclear wave function. In the case of hadron-deuteron scattering, for example, the inclusion of the d-state component of the deuteron wave function is necessary for satisfactory agreement with experimental measurements. The overall success of the model has led to suggestions that it be used to study more subtle effects such as off-shell contributions in the N-N amplitudes,[2] and correlations in the nuclear wave function.[3] The model has been extended to systems in which both target and projectile are composite, and in which simultaneous multiple collisions can occur in addition to the normal, sequential collisions.[4] These extra processes introduce more structure into the differential cross section and thus permit new tests of the parametrizations which enter the model. Deuteron-deuteron scattering is the simplest system in which such effects can be studied.

The effects to be expected can be seen in Fig. 1(a), which shows the contributions of the various scattering terms to the cross section. (The calculation presented here will be described later.) The dominant contribution to the differential cross section at large momentum transfer comes from the simultaneous double-scattering process, in which simultaneous collisions occur between each nucleon of one deuteron with exactly one

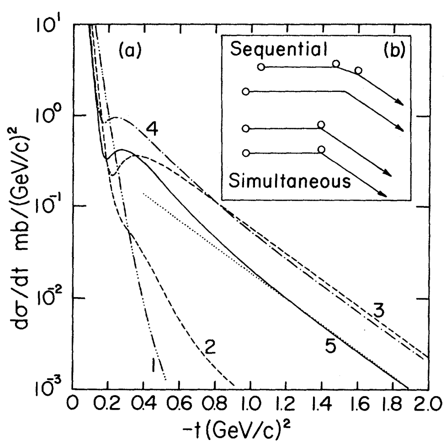

FIG. 1. (a) The cumulative contributions to the cross section of the various terms in the scattering amplitudes. The calculation is discussed in the text. Curve 1 represents single scattering only; curve 2, single plus sequential double; curve 3, single plus simultaneous double; curve 4, single plus both double-scattering terms; curve 5, all terms (i.e., single through quadruple). The dotted line shows the asymptotic slope as given by Kanada, Sakai, and Yasuno (Ref. 5). (b) Diagrams of the two double-collision processes.

nucleon of the other deuteron [see Fig. 1(b)]. In this process the deuterons can be elastically scattered without disturbing the internal momenta of their constituent nucleons. Franco[4] and Kanada, Sakai, and Yasuno[5] have shown that this term is independent of the t dependence of the deuteron form factor, and that the asymptotic slope should be $\frac{1}{2}a$, where a is the nucleon-nucleon slope parameter. This slope is indicated in Fig. 1(a). In the single-scattering region, $-t \leq 0.15$ (GeV/c)^2, the cross section depends on the square of the deuteron form factor, which increases its slope relative to hadron-deuteron scattering. The combination of the steeper single scattering and the increased magnitude of the double scattering causes the region of interference to shift to lower $-t$ [≈ 0.2 (GeV/c)^2], where, as Alberi, Bertocchi, and Bialkowski[6] have pointed out, the contribution from the d-state component of the deuteron form factor does not completely fill the dip in the cross section, in contrast to the case of hadron-deuteron scattering.

No precise experimental examination of the scattering of mutually composite systems has yet been made in the intermediate-energy region. The only statistically adequate measurement of the d-d elastic differential cross section was made by Goggi *et al.*[7] at $\sqrt{s} = 53$ GeV. They observed a well-defined minimum at $-t = 0.18$ (GeV/c)^2. They found discrepancies of up to 25% with the basic Glauber model, but obtained satisfactory agreement with a parameter-free calculation after including the effects of inelastic intermediate states. Earlier bubble-chamber experiments had been performed by Goshaw *et al.*[8,9] Their measurement at 2.2 GeV/c also showed a minimum, located at $-t = 0.25$ (GeV/c)^2. At this momentum, however, there were serious discrepancies in the double-scattering region between the data and their calculation containing all of the multiple-scattering amplitudes. Satisfactory agreement was obtained when only single- and (both) double-scattering terms were included. At 7.9 GeV/c their data are in good agreement with the calculation including all terms, but the statistical errors are so large as to prevent examination of the interference region, and one can only draw rough conclusions about the influence of the double-scattering terms from the data at larger momentum transfer.

This experiment was performed at the Lawrence Berkeley Laboratory Bevatron with apparatus which has been described in detail elsewhere.[10] A 5.75-GeV/c deuteron beam was extracted and focused onto a deuterated (about 97%) polyethylene target. The three-momentum and time of flight of the forward scattered particle were measured in a magnetic spectrometer. A wire chamber and scintillator determined the position and time of flight of the recoil particle. Ten overlapping angular settings spanned the forward laboratory scattering angle from 3.0° to 15.1°. The lower limit was imposed by the minimum detectable recoil kinetic energy, and the upper limit was constrained by the physical layout of the apparatus.

The elastic signal was identified by selecting events for which the measured variables satisfied the four kinematic equations of elastic scattering. The coplanarity distribution was used to estimate the background, which varied from 2 to 18% over the t range of the experiment. A 5.75-GeV/c proton beam incident on a normal polyethylene target provided a p-p elastic-scattering signal, which was used to check the apparatus and analysis procedure.

The results of this experiment are shown in Fig. 2(a), where only statistical errors are indicated. The t resolution is always less than the indicated bin width, and the error (σ) in the overall absolute normalization is estimated to be 10%. We observe a narrow minimum at $-t = 0.18$ (GeV/c)^2, and a significant departure from a simple exponential behavior in the region above the second maximum, where double scattering dominates the cross section. This latter effect has not been explicitly mentioned in the literature, although it is implicitly contained in any multiple-scattering model of this reaction which includes the simultaneous scattering term [c.f. Ref. 4, Fig. 5; Ref. 5, Fig. 2(a); Ref. 6, Fig. 1; Czyż and Maximon,[11] Fig. 10], and an earlier indication of its existence may be seen in the data of Goggi *et al.*[7] Examination of the amplitudes shows that the effect may be understood in the following way. At the second maximum [$-t \approx 0.3$ (GeV/c)^2], the cross section is dominated by three roughly equal amplitudes: the simultaneous double scattering, the sequential double scattering, and the triple scattering. The slope of the sequential amplitude is significantly larger than the (almost equal) slopes of the other two terms, and the phases are such that the sequential term is approximately parallel to the resultant of the remaining terms. The net effect of the rapidly decreasing sequential amplitude is simply a corresponding rapid decrease in the cross section. When the sequential term becomes smaller than the sum of the other two terms, the cross section assumes the more slowly varying behavior of the simultaneous and triple amplitudes. This description is based on a particular set of parameters (to be given later) describing nucleon-nucleon scattering and the deuteron wave function, but its general features are independent of reasonable changes in the parameters.

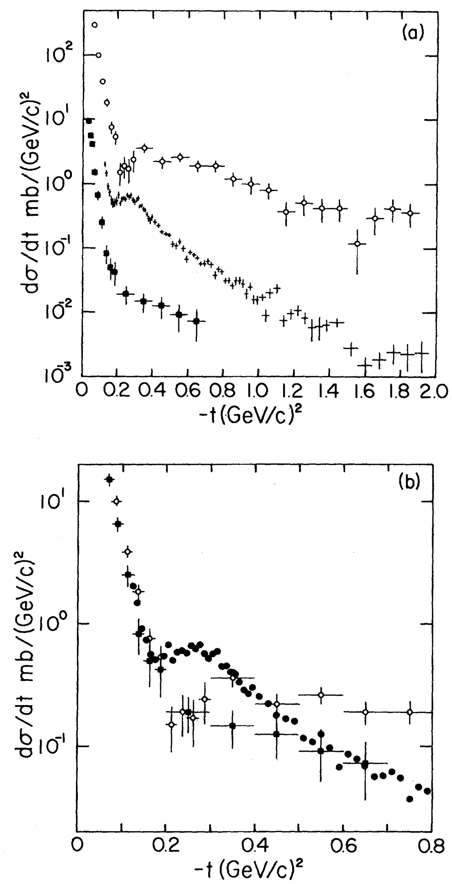

FIG. 2. The results of this experiment compared to the earlier data of Goshaw *et al.*, at 2.2 GeV/c (open circles) and 7.9 GeV/c (closed squares). In (a) the earlier data sets have been shifted by factors of 10 and 0.1, respectively, for clarity. Part (b) shows the interference region, where the present data have been displayed as solid circles without error bars.

In Fig. 2(b) we show a comparison of our results with the intermediate-energy data of Goshaw *et al.*[9] Our few data points in the forward region are in good agreement with the other measurements, which confirms the absolute normalization. Beyond the single-scattering region, however, there is little agreement. The strong energy dependence of the N-N amplitudes below 1.7 GeV/c prevents any meaningful comparison with

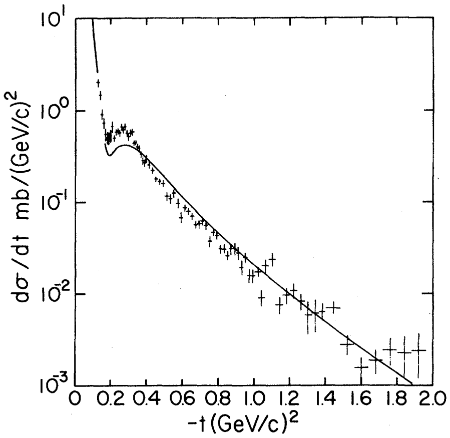

FIG. 3. Data of the present experiment and the calculation discussed in the text.

the 2.2-GeV/c measurement, but the difference between the present experiment and the 7.9-GeV/c data does not seem consistent with reasonable energy dependence of the amplitudes.

Figure 3 shows the result of a calculation[12] in which the d state of the deuteron was taken into account by consideration of terms in the amplitude proportional both to the square of the quadrupole deformation and to the product of the spin-1 operators of the two deuterons.[12] [This calculation was also used to obtain the curves of Fig. 1(a).] The deuteron wave function was obtained from a Reid soft-core potential, and contained a d-state component of 6.5%. The standard parametrization of the N-N amplitudes was used:

$$f(t) = (k/4\pi)\sigma_{tot}(i+\rho)e^{at/2},$$

where $\sigma_{tot} = 43.5$ mb,[13] $\rho = -0.5$,[14] and $a = 6.5$ (GeV/c)$^{-2}$.[15] (The slope parameter is poorly determined in this energy region.) The calculation reproduces several characteristics of the data. In particular, there is good agreement on the absolute cross section in both high- and low-$|t|$ regions, the t location of the minimum and maximum, and the ratio of the cross sections at minimum and maximum. The absolute value of the cross section in the interference region is not well reproduced, however. Since the behavior of the cross section in this region is caused by the near cancellation of various amplitudes, it may be that small differences in the spin and isospin components of the amplitudes play a significant role here and not elsewhere. The effect of intermediate inelastic states may also be important and has not been included in our calculation.

In conclusion, we have produced the first high-statistics, high-resolution data on deuteron-deuteron elastic scattering in the intermediate-energy range. In contrast to earlier data, we have observed a well defined minimum, the location and shape of which is well described by the Glauber multiple-scattering formalism. We have also observed a hitherto unremarked complex behavior of the cross section in the double-scattering region, reflecting the constructive interference of the two double-scattering amplitudes which have different t dependences.

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