Observation of two-proton correlations in *p*Ne interactions at 300 GeV/*c*

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Experimental data reveal a correlation between protons with approximately equal momenta in the reactions $pNe \to mp + X$, $m \geqslant 2$, at a primary momentum $p_0 = 300$ GeV/*c*. The correlation becomes closer as the momenta of the secondary protons increase.

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The experimental data reported here reveal two-proton correlations in *p*Ne interactions at a primary momentum of 300 GeV/*c*. The correlation becomes closer as the momenta of the secondary protons increase, possibly meaning that the dimensions of the region from which the fast protons are emitted are much smaller than the scale dimensions of the target nucleus. Results on two-proton correlations reported previously correspond to much lower primary energies[1] ($\leqslant 40$ GeV), and analysis shows that these correlations are due primarily to a final-state interaction[2–5] of the protons (a nuclear and Coulomb interaction) and identical-particle effects (anticorrelations).[6]

The new results were obtained from an analysis of $\simeq 26\,000$ stereo photographs taken during the bombardment of a 30-inch bubble chamber in a 300-GeV/*c* proton beam at the Fermi National Accelerator Laboratory. As the working liquid in the chamber we used a neon-hydrogen (NeH_2) mixture with 30.9 mole % neon. The procedures for analyzing the photographs, for identifying the type of interaction, and for identifying the secondary particles are described in detail elsewhere.[7] The total number of *p*Ne interactions analyzed was 5792 ∓ 172. For the purpose of studying two-proton correlations we selected *p*Ne interactions which had at least two identified protons. After imposing appropriate limits on the effective region of the bubble chamber and the measurements, we retained for further analysis 2226 interactions of the type $pNe \to mp + X, m \geqslant 2$, with proton momenta restricted to the interval $0.13 \leqslant p \leqslant 1.0$ GeV/*c*.

Two-proton correlations were studied by working with the distributions in the variable

$$d \equiv |\Delta \mathbf{p}| = |\mathbf{p}_1 - \mathbf{p}_2|, \tag{1}$$

where $\mathbf{p}_1$ and $\mathbf{p}_2$ are the momenta of the secondary protons.

Figure 1 shows distributions of the ratio

$$R(d) = N_{\rm expt}(d) / N_{\rm back}(d) \tag{2}$$

for various proton-momentum intervals. Here $N_{\rm expt}(d)$ and $N_{\rm back}(d)$ are the experi-

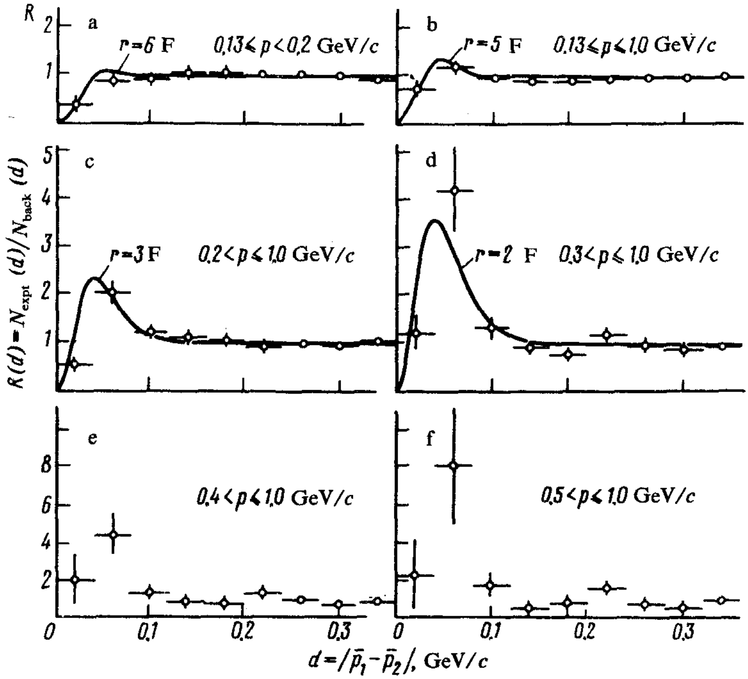

FIG. 1. Distributions in $R(d) = N_{\rm expt}(d)/N_{\rm back}(d)$ for various protom momentum intervals. The curves are theoretical results from Ref. 4.

mental and background distributions, respectively. The background distributions in d were found through a random mixing of the protons (with adherence to the restrictions imposed on the momenta) from different events, but with the same number of protons in the final state. In each of the distributions in Fig. 1 the number of background combinations was at least 100 000. The background and experimental distributions were normalized in such a manner that the ratio $R(d)$ was one for $d \geqslant 0.2$ GeV/c, where the standard two-particle correlation function $R_{12}(p_1, p_2) = R - 1$ is expected to be zero (see Refs. 4 and 5, for example). We might also note that the standard deviation in the determination of d is $\delta d = 0.008$ GeV/c in the interval $0 \leqslant d \leqslant 0.2$ GeV/c and $\delta d = 0.03$ GeV/c at $d > 0.2$ GeV/c.

It can be seen from Fig. 1 that in the distributions in d there are statistically significant deviations from the background distributions at small values of d; these deviations may be due primarily to a final-state interaction and identical-particle effects.[2–5] Shown for comparison in Fig. 1 are some theoretical results which reflect the nuclear and Coulomb interaction of the protons in the final state and also identical-particle effects.[4] The theoretical results are shown for various sizes (r) of the proton emission region and for a zero difference in emission times (τ).

It follows from the data in Fig. 1(a) that for protons with $0.13 \leqslant p \leqslant 0.2$ GeV/c there is a destructive correlation, caused primarily by Coulomb repulsion and the identical nature of the protons. The best agreement with the theoretical results[4] is found with $r \cong 6$ F; this is not a surprising result, since protons with momenta 0.13

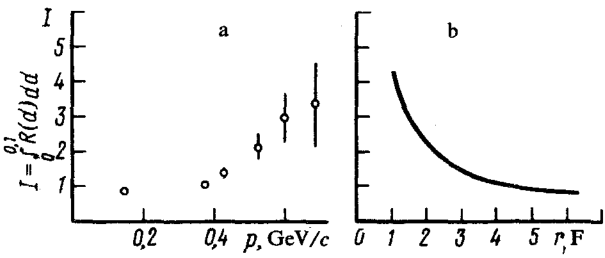

FIG. 2. a—Integral values of $R(d)$ over the interval $0\leqslant d\leqslant 0.1$ GeV/c vs the average proton momentum; b—the same, but plotted against the size of the emission region (theoretical results from Ref. 4).

$\leqslant p \leqslant 0.2$ GeV/c are primarily "evaporation"[8] protons or products of the decay of excited fragments of the neon nucleus (we recall that the rms radius of the neon nucleau is $r_{\rm Ne}\cong 2.8$ F).

As we move toward higher momenta (Fig. 1), the proton correlations become closer; comparison with the theoretical results shows that this closer correlation is evidence of a decrease in the size of the proton emission region with increasing proton momentum. The correlation enhancement can be seen most clearly in Fig. 2, which shows the integrated values of $R(d)$ in the interval $0\leqslant d\leqslant 0.1$ GeV/c vs the average proton momentum. Shown for comparison in Fig. 2b is the theoretical behavior of the integrated values of $R(d)$ in the interval $0\leqslant d\leqslant 0.1$ GeV/c as a function of the size (r) of the emission region.[4] Comparison of the experimental and theoretical results reveals that the scale dimension of the proton emission region decreases with increasing proton momentum; for protons with $\langle p\rangle \cong 800$ MeV/c, for example, we would have $r\cong 1$–1.3 F, which is much shorter than the size of the neon nucleus.

We should point out that the theoretical results of Ref. 4 were found for a zero difference in emission times and for unpolarized protons. An increase in the difference between proton emission times, however, or the appearance of a polarization reduces the two-proton correlations; this effect should increase the estimated size of the emission region. The depenence of $R(d)$ on the proton momentum is much weaker, as has been pointed out elsewhere,[4,5] and, significantly, its influence on the correlation effect is analogous to that described above; i.e., with increasing momenta of the protons thecorrelations between protons should weaken, but this prediction is contradicted by experiment, as can be seen from the data in Fig. 1.

The observed enhancement of the proton correlation with increasing proton momentum can apparently be explained under the assumption that a nucleus contains "associated" nucleons at distances much smaller than the nuclear size.[9]

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