COMPARISON OF THE DIP-BUMP STRUCTURE IN $\bar{p}p$ AND $\bar{p}n$ ELASTIC SCATTERING*

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$\bar{p}n$ and $\bar{p}p$ elastic scattering have been studied in the momentum-transfer region of $t = -0.15$ to $t = -1.0$ $(\mathrm{BeV}/c)^2$ using the reaction $\bar{p}d \to \bar{p}np_S$ or $\bar{p}pn_S$, where p_S and n_S are spectators. The $\bar{p}n$ elastic cross section shows a dip at $t \sim -0.4$ similar to that seen in the $\bar{p}p$ cross section. A comparison of the $\bar{p}n$ and $\bar{p}p$ cross sections shows that they appear to cross over each other, $t \sim -0.4$ $(\mathrm{BeV}/c)^2$.

Evidence has accumulated recently which suggests that $\bar{N}N$ elastic scattering at very low momentum transfer is dominated by the exchange of $I=0$ mesons down to laboratory momenta of at least 1.5 BeV/c.[1,2] The situation is less clear at higher momentum transfers. Assuming $I=0$ meson-exchange dominance of the higher momentum-transfer region, the presence of $I=1$ exchanges can be observed by comparing $\bar{p}p$ with $\bar{p}n$ elastic scattering. Such a comparison has not been previously made. In this note we present $\bar{p}n$ elastic scattering data for momentum transfers out to ~1.4 $(\mathrm{BeV}/c)^2$ at a mean incident momentum of 1.4 BeV/c. In addition $\bar{p}p$ elastic scattering in the same momentum-transfer region has been observed for purposes of comparison with $\bar{p}n$ scattering.

The data in this experiment come from an exposure of the Argonne National Laboratory–Midwest Universities Research Association 30-in. bubble chamber filled with deuterium to an antiproton beam at four different momenta: 1.23, 1.3, 1.46, and 1.65 BeV/c. Throughout the study of quasielastic scattering, every effort was made to treat $\bar{p}p$-like and $\bar{p}n$-like events identically, in order to facilitate direct comparison of the results. In this event sample, both types have been subjected to the same cuts and corrections. An upper limit of 150 MeV/c has been imposed on the momentum of the spectator nucleon in order to give a wide margin against spurious kinematic fits and gross topological distortion on the scanning table.

In quasi $\bar{p}p$ events with neutron spectators, the one-constraint fit always provides information on the spectator. The magnitude of the neutron-spectator momentum is found to be distributed in excellent agreement with the Hulthén deuteron-momentum spectrum, and the direction of the spectator is not correlated with that of any other particle in the reaction.

In quasi $\bar{p}n$ events, the bulk of the spectator protons have unobservable or unmeasurable ranges in the bubble chamber, so that these events are kinematically underconstrained. In these cases, a kinematic hypothesis assuming an unbound target neutron and ignoring the spectator was used. The validity of this approach was demonstrated by applying the same hypothesis to $\bar{p}p$-like events, ignoring the measured proton track, where the fitted spectator momentum corresponded to an unmeasurable range for a proton. Event by event, the shifts in relevant output quantities were always less than the corresponding computed error.

Scanning instructions for quasielastic scattering events were based mainly on the restrictions on angles in equal-mass scattering, with allowances for the effects of parallax and Fermi momentum. A minimum projected scattering angle criterion was included, and a corresponding correction was computed by Monte Carlo methods, assuming isotropy of the scattering plane around the beam direction, and including the effects of Fermi momentum. Independently, this correction gives a slope for the $\bar{p}p$ diffraction peak in agreement with other experiments in this energy region.[3]

The data for $d\sigma/dt$ show no significant differences among the four laboratory momenta in either $\bar{p}n$ or $\bar{p}p$. For this report, the results at all momenta, with the cosine of the center-of-mass scattering angle greater than -0.8, have been grouped together.

The resulting quasi $\bar{p}p$ differential cross section was normalized to the free-$\bar{p}p$ results of Ref. 3 with an uncertainty of 15%. The normalization of our $\bar{p}n$ relative to our $\bar{p}p$ is uncertain to the extent of the difference in small corrections for such nuclear effects as shielding.

Figure 1 shows the $\bar{p}n$ and $\bar{p}p$ differential cross sections obtained in this experiment. The qualitative features of the cross sections are very similar, namely a sharp diffraction peak followed by a dip near $t \sim -(0.3\text{-}0.4)$ and a secondary bump followed by a falloff that is less steep than

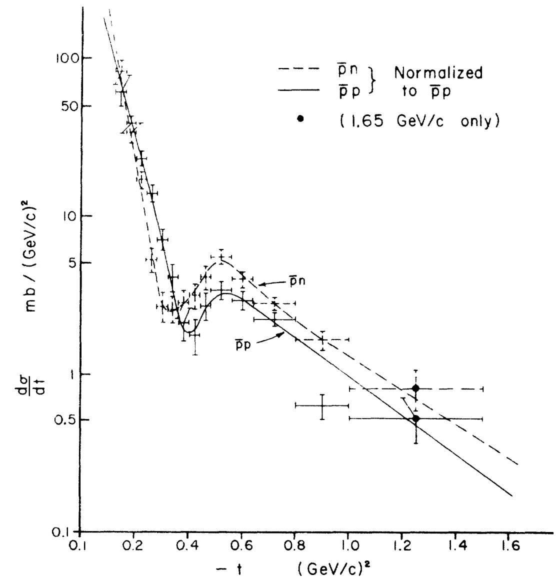

FIG. 1. Comparison of differential cross sections for $\bar{p}n$ elastic scattering (dashed curve and dashed data points) and $\bar{p}p$ elastic scattering (solid curve and solid data points). The curves represent eyeball curves drawn through the data.

the first peak.[3] This qualitative similarity of the two processes suggests that they are dominated by the exchange of a single isospin state. In addition the similarity of the $\bar{p}p$ cross section at 1.4 BeV/c to that observed at higher energies up to 5.9 BeV/c[4,5] suggests that the t channel is responsible for the dip-bump pattern even at the low laboratory momentum of ~1.4 BeV/c.

The differences between $\bar{p}p$ and $\bar{p}n$ scattering are equally interesting. In the dip region, the $\bar{p}n$ and $\bar{p}p$ dips are displaced in a way that is suggestive of interference between $I=0$ and $I=1$ exchanges. In terms of t-channel exchanges the amplitudes for $\bar{N}N$ scattering can be written as

$$A(\bar{p}n)=A(I=0,\ G\pm 1)-A(I=1,\ G=\pm 1),$$

$$A(\bar{p}p)=A(I=0,\ G=\pm 1)+A(I=1,\ G=\pm 1),$$

where I and G refer to the isospin and G parity of the exchanged mesons. Present phenomenological analysis of high-energy reactions suggests that the $I=0$ contribution is due to the exchange of P, P', and ω mesons, whereas the $I=1$ exchange contribution comes from the ρ and A_2 exchanges.[6] If it is assumed that the dip comes from the $I=0$ exchanges as discussed Ref. 6 and that $A(I=1,\ G=\pm 1)$ does not have a zero in the dip region, then the $A(I=0,\ G=\pm 1)$ amplitude must change sign as t sweeps through the dip in order for the $\bar{p}p$ cross section to be greater than the $\bar{p}n$ below the dip and less above the dip.

It should be noted that a simple optical model would also give a dip at the same t value for $\bar{p}n$ and $\bar{p}p$ provided the radius of interaction were similar for scattering from the proton and neutron.

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[1]The $\bar{p}n$ and $\bar{p}p$ total cross sections differ by less than ~10% down to ~1 BeV/c as observed by R. J. Abrams et al., Phys. Rev. Letters 18, 1209 (1967). Using the optical theorem, and assuming a predominately imaginary forward-scattering amplitude, this indicates that the forward $\bar{p}n$ and $\bar{p}p$ elastic amplitudes differ by less than ~10%.

[2]See for example summaries of experimental evidence for high energies given in the Proceedings of the Topical Conference on High Energy Collisions of Hadrons, CERN, 1968 (to be published). In particular, the reports by V. Barger, M. Longo, and M. Perl review much of the existing experimental evidence for isospin independence.

[3]B. Barish, et al., Phys. Rev. Letters 17, 720 (1966).

[4]W. Katz, et al., Phys. Rev. Letters 19, 265 (1967).

[5]R. Rubinstein, A. Ashmore, C. J. S. Damerell, W. R. Frisken, J. Orear, D. P. Owen, F. C. Peterson, A. L. Read, D. G. Ryan, and D. H. White, in Proceedings of the Topical Conference on High Energy Collisions of Hadrons, CERN, 1968 (to be published).

[6]C. B. Chiu, S. Y. Chu, and L. L. Wang, Phys. Rev. 161, 1563 (1967); also V. Barger, in Proceedings of the Topical Conference on High Energy Collisions of Hadrons, CERN, 1968 (to be published).