dispersion parameter D appears to follow the linear dependence on $\langle n_{ch} \rangle$ which has been remarked upon by Wróblewski.[6]

We thank the staff of the 30-in. Argonne National Laboratory–National Accelerator Laboratory chamber, the physicists from the Neutrino Lab at the National Accelerator Laboratory, and members of the 30-in. Spectrometer Collaboration for aid in obtaining our exposure.

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[1]The beam momentum was estimated from main ring parameters (private communication from B. McDaniel) and from magnet measurements in the secondary beam line. The secondary beam was tuned so as to transmit the primary proton momentum, and, consequently, we expect essentially no hadronic background in the beam; from measurement of a sample of beam tracks we expect no more than a few percent of off-momentum protons.

[2]We thank R. Glasser for assisting us in the modification of the reconstruction program for this experiment.

[3]See the Particle Data Group report of O. Benary, L. R. Price, and G. Alexander, UCRL Report No. UCRL-20000NN, 1970 (unpublished).

[4]See the report on 200-GeV/c pp reactions of G. Charlton *et al.*, Phys. Rev. Lett. 29, 515 (1972).

[5]In particular, our results are consistent with those obtained in the 30-in. chamber at 200 GeV/c (see Ref. 4), but not with the Echo Lake cosmic-ray data [see L. W. Jones *et al.*, Nucl. Phys. B43, 477 (1972)].

[6]A. Wróblewski, to be published.

Production of Charged A_2 Mesons at 4 BeV/c*

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The mass spectrum of charged A_2 mesons has been measured in the reaction $\pi^{\pm}p \rightarrow pX^{\pm}$ at 4 BeV/c. More than 3700 events per 5-MeV bin have been recorded at the A_2^+ peak. More than 2600 events per 5-MeV bin have been recorded at the A_2^- peak. The standard deviation of the experimental resolution function is 3.9 MeV. The A_2^+ and A_2^- mass spectra have shapes compatible with a simple Breit-Wigner resonance on a linear background.

The problem of the possible existence of a splitting in the A_2 meson spectrum is of considerable interest because of the incompatibility of A_2 fine structure with the usual quark-model classification scheme of hadrons. The first evidence that the A_2 might possess a split mass spectrum came from CERN in 1967.[1] This missing-mass experiment studied A_2^- mesons produced near the Jacobian peak region in $\pi^-p \rightarrow A_2^-p$ at 6 and 7 BeV/c. In 1968 members of this CERN group again observed the splitting by measuring A_2^-'s produced near threshold.[2] Subsequently, four experiments measuring A_2^+ and A_2^- in $\pi^{\pm}p \rightarrow A_2^{\pm}p$ near threshold and at 7, 17.2, and 20.3 BeV/c failed to observe A_2 fine structure.[3] However, an experiment measuring the A_2^0 mass spectrum in $\pi^-p \rightarrow A_2^0n$ at 3.16 BeV/c did find evidence for splitting.[4] Although this supposedly schizophrenic behavior of the A_2 might be explained by peculiarities of the dynamics, the results of a recent experiment by Bowen *et al.* contradict the original CERN experiment.[5,6] We have performed a high-statistics, high-resolution experiment in the hopes of contributing to the solution of the A_2 puzzle.

In an experiment performed at the Argonne National Laboratory zero-gradient synchrotron, we have studied the mass spectrum of charged A_2's by measuring the missing-mass recoiling from the proton in $\pi^{\pm}p$ interactions at 4 BeV/c. The mass resolution has $\sigma = 3.9 \pm 0.2$ MeV. We have more than 200 000 events of both charges between 1.20 and 1.43 BeV. The t' interval covered is from -0.12 to -0.72 (BeV/c)^2.[7]

The experimental layout is shown in Fig. 1. The beam direction was measured with six multiwire proportional chambers. The momentum of each beam particle was determined by proportional chambers located at a momentum-dispersed focus of the beam.[8] A gas Cherenkov

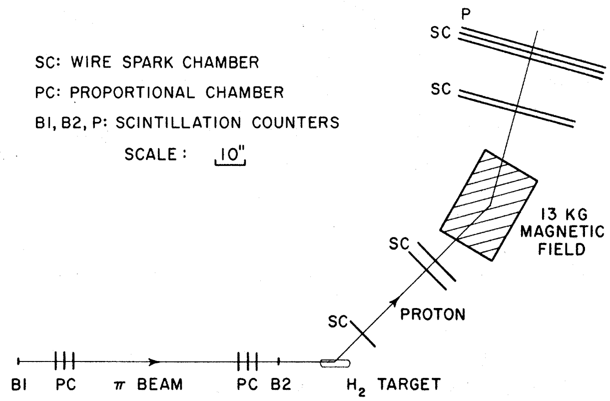

FIG. 1. Plan view of the experimental layout.

counter C was used in the beam to distinguish pions from heavier particles. The beam struck a 10-in.-long, 2-in.-diam hydrogen target. The beam axis was 0.69 in. from the H_2 target axis in order to minimize the multiple Coulomb scattering of the recoil proton. A small counter B, subtending 7×10^{-4} sr at the H_2 target, determined if the beam particle interacted. The final-state proton momentum and production angle were measured with a wire-spark-chamber magnetic spectrometer consisting of seven wire spark chambers and a magnet with a 13-kG field. Time-of-flight information, using scintillation counters B_2 and P, distinguished protons from other final-state particles.[9] The amount of scattering material encountered by the proton, before its angle was determined, was minimized. The trigger for the system was $CB_1B_2\bar{B}P$. An on-line PDP-15 computer was used to monitor the operation of the chambers and scintillation counters. The raw data were stored on magnetic tape for final analysis on the Indiana University CDC 6600 computer.

Several subsidiary experiments were performed to check the A_2 mass resolution.

(1) We studied the π^-signal in the missing-mass spectrum of the reaction $\pi^-p\to pX^-$ at 1.0 BeV/c at the beginning and end of the A_2 run. Prominent pion peaks were observed, with m_π^2 equal to 0.019 and 0.022 BeV^2. The experimental widths had a standard deviation of 0.009 BeV^2. The first of these peaks is shown in Fig. 2(a). We anticipated that the π peaks would be at 0.0195 ± 0.004 BeV^2 and would have a width of 0.010 BeV^2.[10]

(2) The deuteron signal in a missing-mass measurement of $pp\to\pi^+X^+$ at 1.4 BeV/c is shown in Fig. 2(b). The deuteron peak is at a mass of

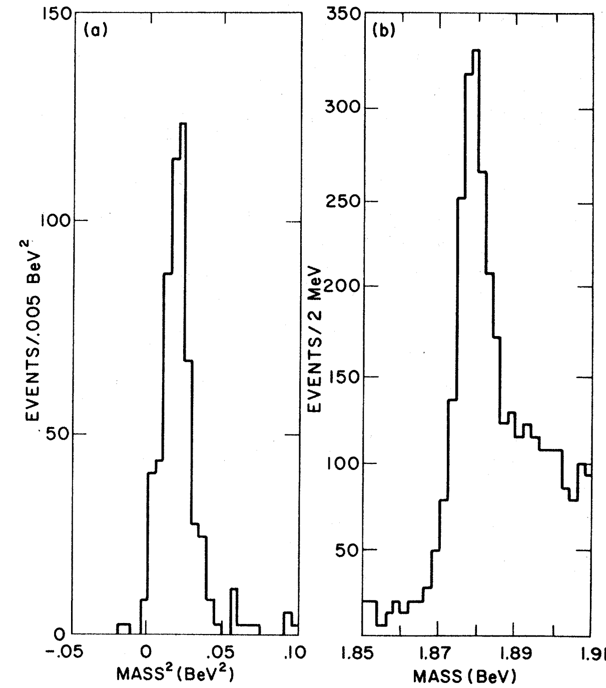

FIG. 2. (a) The spectrum of the square of the missing mass in the reaction $\pi^-p\to pX^-$ at 1.0 BeV/c. (b) The missing-mass spectrum in the reaction $pp\to\pi^+X^+$ at 1.4 BeV/c.

1.879 BeV with an experimental width having $\sigma=3.1$ MeV. This agrees well with our expectation of a mass 1.8755 ± 0.0055 BeV and $\sigma=3.6$ MeV.

(3) Before and after the A_2 running, the liquid-hydrogen target was replaced by a production target consisting of 40 thin, vertical wires. The reconstructed vertices of the wire-target events, projected onto a horizontal plane, were compared with the known absolute position of the wires to check the resolution of the proton angle measurement.

We also studied the results of target-empty runs and runs with the proton magnet off. We performed tests to show that the velocity of sound along the magnetostrictive wands was constant and tests to measure the spatial resolution of the proportional chambers and wire spark chambers.[11] We continuously monitored the one- and two-dimensional particle distributions in all spark and proportional chambers during the experimental runs. The proton spectrometer arm was in the same position for all tests and runs.

The results are shown in Fig. 3.[12] Figure 3(a) shows the total A_2^+ and A_2^- data samples, $-0.72\leq t'\leq-0.12$ BeV/c^2, while Fig. 3(b) displays the

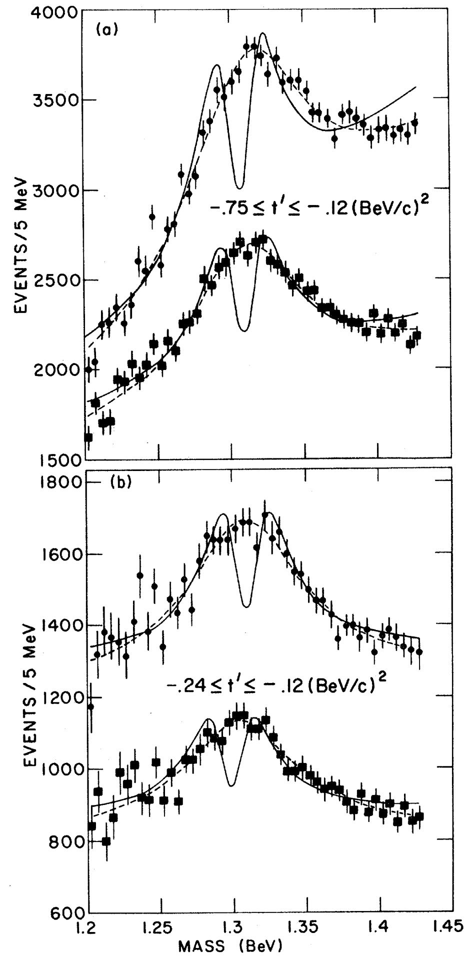

FIG. 3. The missing-mass spectra for $\pi^{\pm}p \rightarrow pX^{\pm}$ at 4 BeV/c. The circles and squares represent X^+ and X^-, respectively. See the text for a discussion of the smooth curves.

data for $-0.24 \leq t' \leq 0.12$ (BeV/c)^2. The mass resolution for the data in Fig. 3(a) has $\sigma = 3.9$ MeV, while for Fig. 3(b) the corresponding value is 4.2 MeV. We note that the mass resolution in this experiment is significantly better than previous missing-mass experiments.[13]

The smooth curves in Fig. 3 represent fits to the data using a Breit-Wigner with a linear background (the dashed curves) and a dipole with a linear background (the continuous curves).[14] The theoretical curves were folded with a Gaussian resolution function. The χ^2 values for the eight smooth curves are given in Table I. In all cases, the Breit-Wigner fits are consistent with the data and the dipole fits are statistically unsatisfactory. For the ten bins centered about 1.310 BeV, the confidence levels for the dipole fits are all less than 10^{-4}. We have examined scores of mass

TABLE I. Values of χ^2 for Breit-Wigner and dipole fits to the data. The first two columns are for the complete t' bite and correspond to the curves in Fig. 3 (a). The second two columns are fits to the data in Fig. 3 (b). All fits have 43 degrees of freedom.

	A_2^+	A_2^-	A_2^+	A_2^-
Breit-Wigner	60.3	46.8	43.5	33.9
Dipole	397	273	119	101

plots having different t' or t bites, and with different vertex cuts to improve the experimental mass resolution. In all cases, the data were consistent with the A_2 meson having a simple Breit-Wigner shape.[15]

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[6]In Refs. 1–5 we arbitrarily include only those A_2 experiments which detected more than ~ 500 A_2's with a resolution having a standard deviation $\lesssim$10 MeV. Several experiments that we do not quote do show evidence of A_2 splitting. For a complete list of A_2 references, see P. Söding *et al.*, Phys. Lett. 39B, 1 (1972).

[7]At the A_2 mass, this corresponds to a momentum-transfer range of -0.18 to -0.78 (BeV/c)^2.

[8]The beam-momentum resolution had a full width at half-maximum of 16 MeV/c. The absolute momentum

of the beam was determined with each of the two beam stages from the excitation curves for the dipole magnets. After about 15% of the experiment was completed it was discovered that two quadrupoles were misaligned. These quadrupoles were adjusted. This changed the calculated beam momentum for the corresponding stage by 0.5%. This correction was made to the early 15% of the data. At 4 BeV/c, the two stages disagreed in their prediction of the absolute beam momentum by less than 0.1%. A 0.1% change in the beam momentum corresponds to a shift in the A_2 mass scale of approximately 0.8 MeV.

[9]The proton-momentum resolution had a σ better than 1.1% for all momenta. (For calculating the A_2 mass resolution, $\sigma = 1.1\%$ was used for the momentum resolution of the recoil proton.) The time resolution had $\sigma = 0.4$ nsec. The proton path length was ~ 3.5 m. Thus, it was trivial to eliminate the 5–10% of events caused by triggers due to π's, K's, or d's in the proton arm.

[10]In the determination of the absolute beam momentum, the two beam stages disagreed by 1.2% at 1 BeV/c. (The exitation curves are not accurately measured for all the magnets at this low momentum.) This corresponds to an uncertainty of the location of the π peak of 0.007 BeV^2.

[11]The spatial resolution for the proportional chambers, which had 2-mm wire spacings, had $\sigma = 0.8$ mm. For the spark chambers, which had 1-mm wire spacings, σ was 0.6 mm.

[12]Figure 3 shows results that are weighted to correct for the geometric acceptance. The average weight from 1.275 to 1.355 BeV is 1. The weight varies gradually in this region, changing by about 12% and 32% for the data in Figs. 3(a) and 3(b), respectively.

[13]For each event the standard deviation of the resolution function is calculated. The calculation uses the information given above in Refs. 8, 9, and 11, and determines the proton multiple Coulomb scattering by the Rosenfeld formula from Ref. 6. The scattering in the aluminum wires in the first proton spark chamber is treated statistically. We include the effects of the off-diagonal terms in the error matrix. The σ's for the individual events have a distribution with a full width at half-maximum of 2.4 MeV and an average value of 3.9 MeV.

[14]The formulas that we used are given in Ref. 5. The width of the Breit-Wigner resonance was fixed at 95 MeV in these fits. A dipole width of 28 MeV was used.

[15]The distribution most suggestive of a dipole shape is an A_2^- plot with $-0.45 \leq t \leq -0.25$ (BeV/c)^2 and a vertex cut which reduces the experimental resolution —for this t range—from 3.5 to 3.4 MeV. The data discarded by the vertex cut have a resolution of 3.8 MeV. At the A_2^- peak there are 750 events per 5 MeV. These data were fitted by the Breit-Wigner and dipole formulas. The χ^2 values for 43 degrees of freedom were 59.2 and 90.9, respectively. The results were sensitive to the binning.

Resonant Spin Rotation—a New Lepton $g-2$ Technique*

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We describe an extension of the Michigan g-factor work that permits measurement of the $g-2$ precession frequency of free leptons by a resonance technique. Preliminary results with electrons (accurate to about 100 ppm in the anomaly) indicate that the technique may be of use in various future experiments.

Recent precision measurements of lepton g-factor anomalies can be classified as being either "precession experiments" or "resonance experiments," depending on the technique employed.[1] Precession experiments include measurements of the electron,[2] positron,[3] and muon[4] anomalies. The characteristic feature of these experiments is a direct observation of the spin