different parametrization schemes are more indicative of the true uncertainties than are the quoted errors.

Probably the most reliable analyses are ARAI 80, CRAWFORD 80, AWAJI 81, FUJII 81, CRAWFORD 83, ARNDT 90B, and LI 93. The Listings include our estimates of the couplings, using the results of these analyses. The errors we give are a combination of the stated statistical errors on the analyses and the systematic differences between them. The analyses are given equal weight, except LI 93 is weighted, rather arbitrarily, by a factor of two because its data set is at least 50% larger than those of the other analyses and contains many new high-quality experimental measurements.

The Baryon Summary Table gives $N\gamma$ branching fractions for those resonances whose couplings are considered to be reasonably well established. The $N\gamma$ partial width Γ_γ is given in terms of the helicity amplitudes $A_{1/2}$ and $A_{3/2}$ by

$$\Gamma_\gamma \;=\; \frac{k^2}{\pi}\frac{2M_N}{(2J+1)M_R}\left[\,|\,A_{1/2}\,|^2 + |\,A_{3/2}\,|^2\right] \;.$$

Here M_N and M_R are the nucleon and resonance masses, J is the resonance spin, and k is the photon c.m. decay momentum.

The Listings contain several results for the E2/M1 ratio ($E^{(3)}_{1+}/M^{(3)}_{1+}$) of the $\Delta(1232)$. The analysis of TANABE 85 attempts to distinguish between renormalized and bare couplings; it is, therefore, a model-dependent result and should not be compared directly with the others. Similarly, Christillin and Dillon [3] have made a model-dependent estimate of the ratio. They do not fit directly to data, so their value does not appear in the Listings, but they conclude that the ratio is between zero and -2%. DAVIDSON 90 extracts the K-matrix residues for M_{1+} and E_{1+} using the data from several energy-independent analyses of the $\Delta(1232)$ region. Essentially, they are measuring $\mathrm{Im}(E^{(3)}_{1+})/\mathrm{Im}(M^{(3)}_{1+})$. The value quoted in the Listings is their average over several fits. DAVIDSON 91 uses an effective Lagrangian model to fit to various partial-wave analyses in the $\Delta(1232)$ region.

Christillin and Dillon point out that the spread in predictions may be due to the difference between bare and renormalized couplings. Since the separation of these is essentially model dependent, WORKMAN 92 measures $\mathrm{Im}(E^{(3)}_{1+})/\mathrm{Im}(M^{(3)}_{1+})$ directly from experimental data using the methods of ARNDT 90B. Whereas the other measurements are dependent on rather old partial-wave analyses, WORKMAN 92 uses recent experimental data. They also perform a fit, based on the model of Nozawa *et al.* [4], to extract "bare couplings," and get -3.9%.

The Listings also contain several measurements of the magnetic moment μ_Δ of the $\Delta(1232)^{++}$ from analyses of pion bremsstrahlung, $\pi^+ p \to \gamma\pi^+ p$. NEFKENS 78 is an analysis of UCLA data for pion bremsstrahlung that uses the soft pion model of Pascual and Tarrach [5]. HELLER 87 is a fit to the same data using a nonrelativistic dynamical model that measures the magnetic moment of the "bare" $\Delta(1232)^{++}$. LIN 91B fits the data of NEFKENS 87 and from SIN [6] with an amplitude that includes the anomalous magnetic moment of the $\Delta(1232)$ and is relativistic, gauge invariant, and consistent with the soft photon theorem. The quantity measured is not identical to the "bare" magnetic moment since it does not take into account the effect of loop contributions. BOSSHARD 91 measured the polarized target asymmetry in pion-proton bremsstrahlung and fit it using the model of HELLER 87. The geometry of the experiment was chosen to maximize the sensitivity to μ_Δ.

See our 1992 edition [1] for brief discussions of Compton scattering, $K\Lambda$ photoproduction, and pion electroproduction.

References for Section IV

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V. Outlook

(by D.M. Manley, Kent State University)

It is anticipated that much new data related to the study of nucleon resonances will come from experiments with electromagnetic probes at CEBAF, which will initially provide beams of electrons and photons with energies up to 4 GeV. Such experiments form the major component of the approved research program for CEBAF's Hall B, which is currently expected to begin operation in Fall, 1996. Other experiments to study nucleon resonances and/or elementary electroproduction or photoproduction reactions will be carried out in CEBAF's Hall A and Hall C, which are expected to being operation in mid-1995 and mid-1994, respectively. The main detector for the Hall-B experiments is the CLAS (CEBAF Large Acceptance Spectrometer), which, with CEBAF's 100% duty cycle, will make possible studies of electroproduction reactions such as $p\,(e,e'\pi^+)n$, $p\,(e,e'p)\pi^0$, $d\,(e,e'\pi^-)pp$, $p\,(e,e'p)\eta$, and $p\,(e,e'p)\omega$, among others. This facility will also use tagged photons to make high-precision measurements of the differential cross section for reactions such as π^0, η, and η' photoproduction. These experiments are expected to improve determinations of the electromagnetic couplings of resonances such as the $\Delta(1232)\,P_{33}$, the $N(1520)\,D_{13}$, the $N(1535)\,S_{11}$, and the $N(1680)\,F_{15}$, which have large photocouplings; they are also expected to provide new information about resonances that couple weakly to the πN channel.

CEBAF is not the only laboratory where new experiments to study nucleon resonances will be carried out. For example, the new Bonn continuous beam machine ELSA will combine two large solid-angle detectors, PHOENICS and SAPHIR, with tagged photon facilities to increase our database from various photoproduction processes [1]. Other facilities are or will