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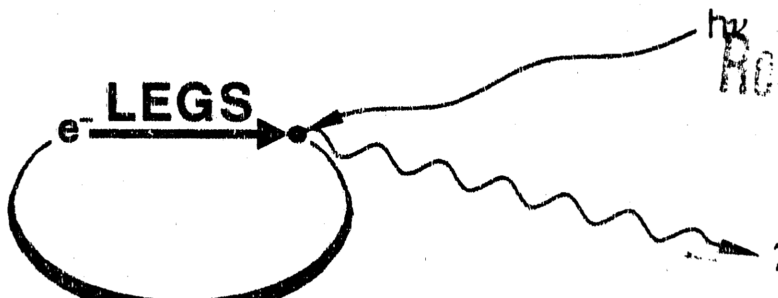

A Polarized Look at Nucleons

The LEGS Collaboration:

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LASER ELECTRON GAMMA SOURCE

BROOKHAVEN NATIONAL LABORATORY
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A Polarized Look at Nucleons*

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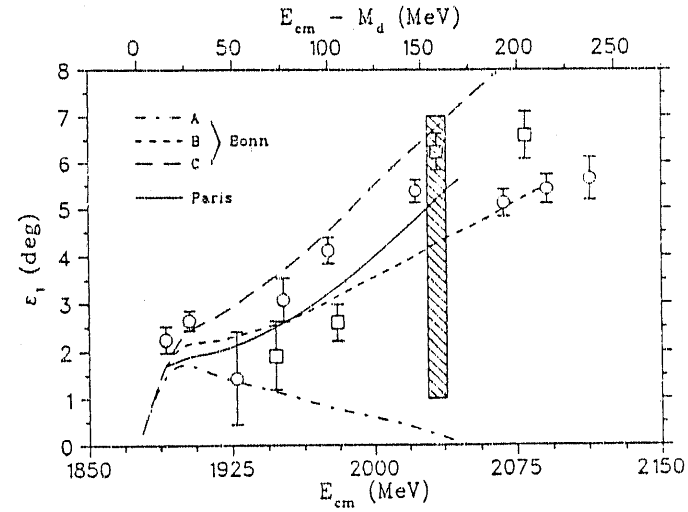
As the title suggests we are going to look at reactions induced on nucleons by polarized photons. The results I am going to show today are from the Laser Electron Gamma Source, or 'LEGS' facility, at Brookhaven National Laboratory. At LEGS, gamma ray beams are produced by backscattering laser light from relativistic electrons. I will only summarize the main characteristics of this facility, and leave an in depth description to Dr. Schaerf who will discuss LEGS and other similar backscattering facilities on Wednesday.

Reactions with polarized photons inevitably reflect interference terms that for the most part remain hidden in spin-averaged unpolarized measurements. This provides a tool for probing interactions that depend upon spin. In particular, we are going to look today at two cases where the polarization is used to probe the tensor interaction. First, we will examine the tensor force between a proton-neutron pair in deuterium. (A subset of these data were published this Fall in Physical Review Letters[1].) Secondly, we will examine the tensor force between quarks in a proton that produces a small E2 component that is mixed with the predominantly M1 excitation of the delta resonance. As Dr. Drechsel discussed this morning, the magnitude of this E2 component provides a sensitive probe of the structure of the Nucleon.

Polarized Photons from LEGS, the Laser Electron Gamma Source

The LEGS collaboration, as you can see from the author list, consists of a group of about twenty physicists from both National Labs and Universities. At LEGS, laser light is collided with electrons in the X-Ray ring of the National Synchrotron Light Source[2]. This is a 2.5 GeV storage ring at Brookhaven. Compton scattering produces a continuous spectrum of photons up to a maxium at the associated Compton edge, the position of which can be adjusted by changing the wavelength of the laser. The average gamma-ray flux at LEGS is about two-thirds times 10^7 photons per second. This is chiefly an administrative limit since the backscattering process reduces the lifetime of the storage ring. This limit fixes the integrated area of the backscattered spectrum. The resolution of the gamma-ray beam is about 5.5 MeV, defined by tagging in a magnetic spectrometer, that is by catching the electrons that give up some of their energy to make the backscattered photons, and measuring this in coincidence with a nuclear reaction event. The attribute that makes this type of photon source unique is its polarization. The spin-flip

The values of ε_1 extracted from phase shift analysis are shown in the figure, as a function of center-of-mass energy in the n-p system. Also plotted are the predictions from various calculations, the A, B, and C versions of the Bonn OBEPQ potential, as well as the predictions for the Paris potential. Two sets of points are plotted, circles and squares. These are two different phase shift analysis. The circles are by Bugg[4], and the squares are by Arndt[5]. You will notice that, in many cases, the points from the different analyses do not overlap. The



errors on these points are traced by propagating the statistical as well as the systematic errors in the scattering data through the phase shift analyses. The error bars are the diagonal elements of the error matrix, and this is the picture that is usually used by most authors of potential models to try to fix the short range part of the tensor force. However, what is almost always overlooked is the fact that this error matrix, from which the vertical bars on these points are derived, is not diagonal. In particular, it has large off-diagonal elements.

There has been a recent attempt, by Chulick and collaborators[6] to study the effects of these off-diagonal elements. They performed an analysis at one energy near 2050 MeV in the center of mass, 325 MeV on a fixed target, and tried to include the maximum effect of the systematic as well as the statistical errors in the scattering data. Their result is shown as the crossed hatch area in the figure. As you can see, it is very much greater than the error bars that reflect only the diagonal elements of the error matrix. The large extent of this hatched region indicates the shallowness of the χ^2 minimum. There is a general feeling in the community that this error band may be a bit too pessimistic, but nonetheless it does expose the sensitivity to the off-diagonal error matrix elements, and certainly indicates that the true errors are significantly larger than the vertical bars on the points.

That being the case, what does one do? It is clear that it is very difficult to take these phase shift data and pin down the short range part of the tensor interaction. These results come from elastic scattering, but of course one can look at reaction channels. On the top scale of the figure I've plotted the energy in excess of the bound state of the deuteron. If the neutron and the proton come together and fuse, then this is the amount of energy that would be available. In particular, for a reaction in which the deuteron was left behind and a 200 MeV gamma ray carried off the excess energy, one would expect a reasonable separation between the predictions of the various potential models. That's what I'd like to turn to now but I'll turn the reaction backwards in time and look at deuteron photo-disintegration. This is a two-body reaction that takes place entirely in a plane. We need a spin observable to be sensitive to a tensor force and so we'll consider this reaction initiated by linearly polarized gamma rays. In that case we can define the azimuthal angle as being the angle between the electric vector of the linearly polarized photon and this reaction plan. When the electric vector is in the reaction plane or at 90° to it, we call the geometry parallel or perpendicular, respectively. The beam polarization asymmetry is then simply the difference between the parallel and perpendicular cross sections divided by the sum. For photon energies near 200 MeV this asymmetry reveals appreciable sensitivity to the tensor interaction. At extreme forward and backward angles the asymmetry vanishes, but this is simply because the azimuthal polarization angle becomes undefined, and the difference of two cross sections measured with undefined azimuthal angles cancels.

However, at angles near 90° the asymmetry becomes appreciable and the potential model predictions are well separated. Previous surveys of this reaction have been conducted, most noteably at Khar'kov[7], however, the errors on the measured asymmetries have been too large to effectively constrain the calculations.

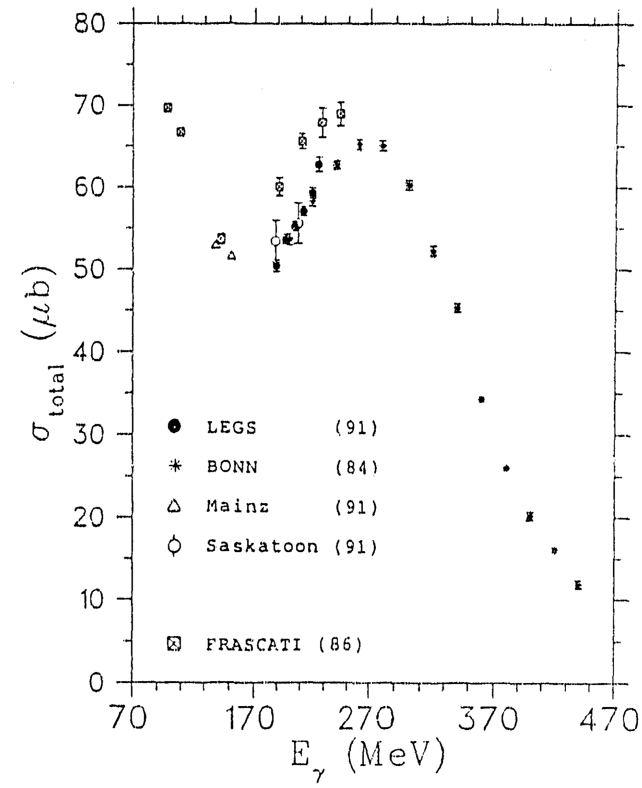
We have completed a new set of photo-disintegration measurements on the deuteron at LEGS. These measurements involved two independent sets of detectors surrounding a liquid deuterium target. One set consisted of 24 phoswich detectors, arranged in sets of three at eight different angles. These units are sandwiches of two types of scintillator, giving both energy loss and total energy information that allowed the identification of protons. The other detector was comprised of a set of microstrip detectors that were able to accurately reconstruct the reaction angle of the proton. This array was backed by a high resolution sodium iodide crystal that measured total energy. The data from the phoswich detectors were analyzed only tagged, requiring an electron in the tagging spectrometer to defined the energy of the photon that initiated the reaction. The microstrip detectors were analyzed untagged, that is using just the angle information and energy to reconstruct what the gamma-ray energy must have been to produce the reaction. Here, the tag information was used only to tell us when to stop this reconstruction process so as to avoid backgrounds from three-body decays involving a pion in the final state.

The photo-disintegration of deuterium has a rather unfortunate history going back many years. If you look at the literature it seems that any time this cross section is measured a different answer is reported. That's quite troublesome because before you can deduce anything from a polarization observable you must fix the scale of the reaction via the total cross section. In all early experiments the gamma-ray energy was not directly measured. Rather, two-body kinematics was assumed to reconstruct what the gamma-ray energy must have been. The spread among these data sets is very large. Fortunately, a number of tagged photon experiments, in which the kinematics have been over determined, have been completed in recent years, and these agree very well.

Throughout the angular range, the differential cross sections from the two recent LEGS measurements[1] agree very well, both with each other as well as with tagged bremsstrahlung experiments from Bonn[8] and from Mainz[9]. Similar agreement is seen in the total angle-integrated cross section, as shown in the figure. Here some recent tagged bremsstrahlung data from Saskatoon have been included[10], and these are also in quite good agreement. There is another data set where something was known about the photon energy. This is from Frascati[16], and is shown as the crossed-boxes. In these measurements, the photon beam was produced by positron annihilation in flight. This process produces a peak in the gamma-ray spectrum but is accompanied by a rather large tail which greatly complicates the analysis. Above 140 MeV these data rise significantly above all of the tagged measurements.

We have basically converged, in that all of the tagged photon facilities are really giving the same answer, so now we really can turn our attention to the polarization observables and see what there is to learn. The next figure shows the new LEGS polarization asymmetry data near 200 MeV. There are two features of these data that should be noted. First, the error bars on the LEGS points are smaller than previous measurements. This simply reflects the higher degree of polarization in the beam. All previous measurements were made with coherent bremsstrahlung in single crystals, which is a difficult technique that produces a lower degree of polarization. The second feature to note is that the new data points from LEGS are somewhat more smooth and continuous. This is really a reflection of the fact that the data were taken at all angles and all energies simultaneously, which gives a much better handle on systematics.

The curves in this figure are calculations from Dr. Arenhoevel and collaborators[11], using the same OBEPQ potentials as we have been discussing. If we were to consider only the asymmetry data, curve B seems to give the best representation of the data, and this is indeed confirmed by a chi-squared analysis. However, the story does not end here. As can be seen in the next equation, the cross section for this reaction can quite generally be written as the average of the parallel and perpendicular cross sections, plus P, the degree of linear polarization, times the average difference cross section, multiplied by cos(2ϕ), where ϕ is the azimuthal angle between the electric vector of the linearly polarized photon and the reaction plane. The average of the parallel and perpendicular cross sections is just what you would measure with an unpolarized photon beam. I will call the average difference, Δ. It is Δ and the unpolarized cross section that are the linearly independent observables here. The asymmetry, sigma, is simply their ratio. The figure shows all of these observables plotted together with the predictions A, B, and C, using the three versions of the OBEPQ potential. Other published unpolarized and asymmetry measurements are also shown. There are no previous determinations of Δ. The first thing we can see here is that the predictions of these three different potentials for the unpolarized cross section are all indistinguishable. There is no sensitivity whatever in the unpolarized cross section to the tensor force. All the sensitivity comes in Δ, the average of the polarization difference cross sections. This sensitivity appears also reflected in the beam asymmetry, sigma, simply because Δ is the numerator of this ratio. Thus, the apparent agreement of curve B with the asymmetry data is completely fortuitous. These calculations reproduce neither the unpolarized cross section nor Δ. These discrepances appear to cancel in the asymmetry simply because curve B is about as low in the unpolarized cross section as it is less negative in Δ. It is the polarization difference cross section, Δ, that is the relevant quantity for extraction of the tensor force, not sigma. The apparent discrepancy between the data and the calculated unpolarized cross section, using the Bonn potentials, had been a puzzle for some time. This has recently been identified by Dr. Arenhoevel as being due not to the N-N potential itself but rather to how the isobar currents were



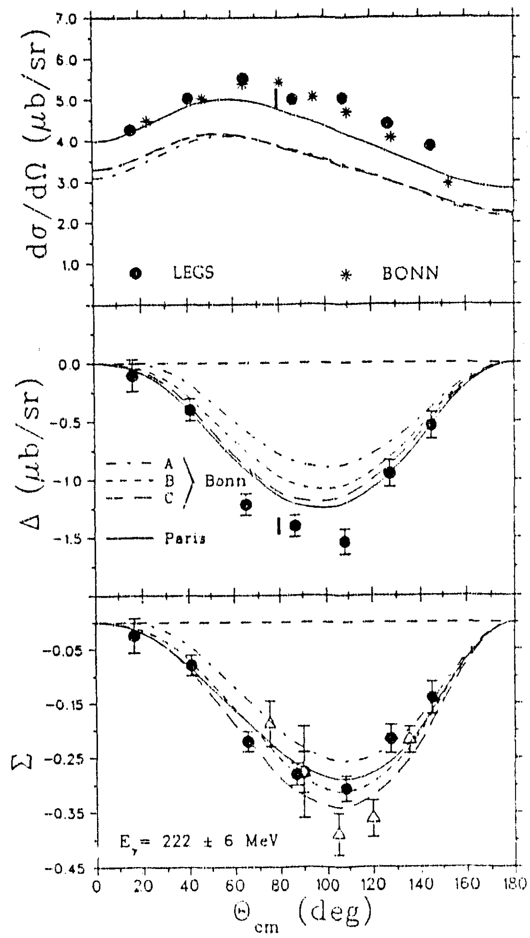
$$\frac{d\sigma}{d\Omega}(\theta,\phi) = \frac{1}{2}\left[\frac{d\sigma_{||}}{d\Omega}(\theta) + \frac{d\sigma_{\perp}}{d\Omega}(\theta)\right] + P \cdot \frac{1}{2}\left[\frac{d\sigma_{||}}{d\Omega}(\theta) - \frac{d\sigma_{\perp}}{d\Omega}(\theta)\right] \cdot \cos(2\phi)$$

$$= \frac{d\sigma}{d\Omega}(\theta) + P \cdot \Delta(\theta) \cdot \cos(2\phi)$$

$$\Sigma(\theta) = \Delta(\theta) \,/\, \frac{d\sigma}{d\Omega}(\theta)$$

included in the calculations. This is now in the process of being corrected. Based on some preliminary tests, we fully expect that when this work is complete the calculations with these Bonn potentials will be able to successfully predict the unpolarized cross section. At that point we should be able to use the measured values of Δ to constrain the tensor interaction in the Bonn N-N potential.

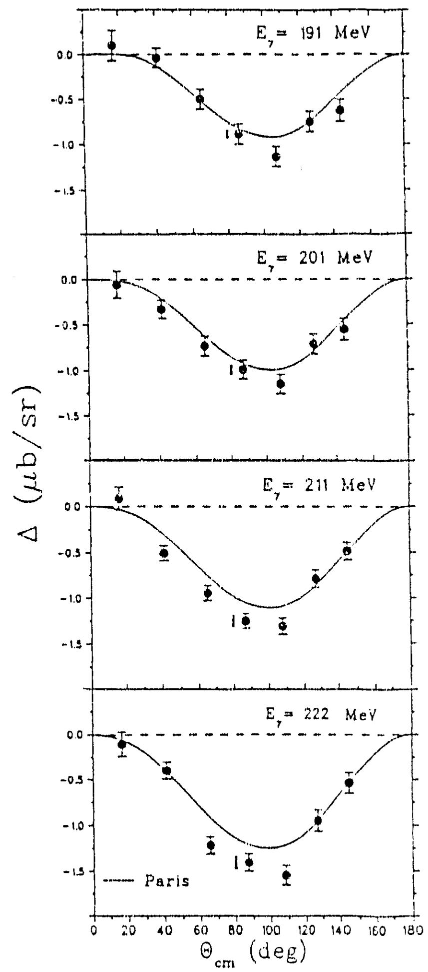
The interpretation of the calculations using the Paris potential is more straight forward. The vertical bar at 80° in each panel of the figure indicates the extent of the systematic uncertainty in the LEGS data set. Allowing for this uncertainly, the predictions using the Paris potential provide a reasonable representation of the unpolarized cross sections. That being the case, we can now turn our attention to Δ and see what we can learn about the tensor force in the Paris potential. At energies near 190 MeV these calculations are in fairly good agreement. But as the energy increases the Polarization difference data become systematically more negative than the calculations. There are two possible sources for this. One is simply that the tensor force in the Paris potential was adjusted to fit values of the phase shift parameter ε_1, but assuming unrealistically small errors, and it may have to be readjusted. The other possible problem may lie in the fact that these calculations treat the N-Δ and Δ-Δ interactions in exactly the same way as the N-N force. As we approach the peak of the delta, about 265 MeV in deuterium, this has to have some effect. The better approach would be to treat these interactions in a couple channel calculations framework. This, I understand from Dr. Arenhoevel, is now being developed. So, in conclusion, we are well on the way towards being able to constrain the Nucleon-Nucleon tensor interaction by comparing model predictions with the polarization difference cross sections observed in deuteron photodisintegration.



The Tensor Force between Quarks in a Proton

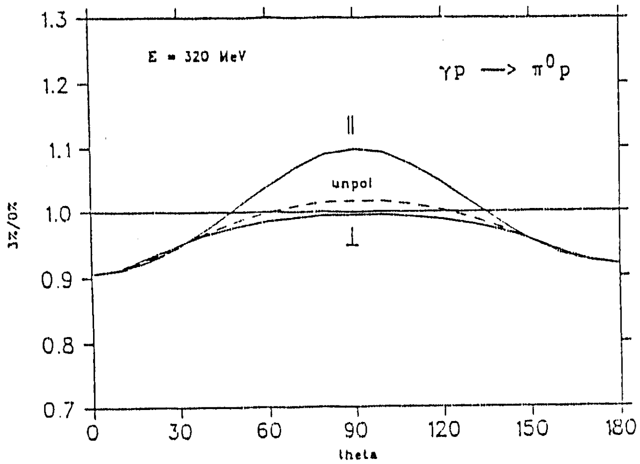
I'd now like to turn to the second example of Tensor forces probed with polarized photons. This concerns the E2/M1 mixing ratio in the excitation of the delta resonance. Essentially all constituent quark models invoke a tensor interaction between the quarks in a proton which comes about through one-gluon exchange, just as the Nucleon-Nucleon tensor force comes about mainly through one pion-exchange. Now, in complete analogy with the N-N interaction, this tensor force between quarks mixes in a D state into what would otherwise be a purely S wave proton. The magnitude and sign of this D state component is quite sensitive to how the internal structure of the proton is treated in quark models.

The experimental signature of such a D wave component would lie in the excitation of the nucleon to its first excited state, the delta resonance, at about 320 MeV. The delta is excited mainly by M1 photons. Magnetic dipole transitions flip spin, so that in this excitation the proton wavefunction is changed from a uud quark configuration to a uuu configuration, with the result that the nucleon spin is changed from 1/2 to 3/2. If there is a D wave component in the delta then this transition can also be excited by an E2 photon. The problem is in understanding the relative magnitude of this E2 excitation compared to the dominant M1 transition. A variety of models predict this mixing ratio to be quite small, anywhere from -0.9 to -4%.



The delta is most readily observed in photo-pion production. In charged-pion production, however, the delta excitation interfers with a rather large non-resonant background. This makes it very difficult to extract a small E2 interference term from this channel. The situation is much more favorable in neutral-pion production. There are still backgrounds in this channel but they are greatly reduced. The amplitudes for photo-pion production are usually given in terms of the angular momentum of the outgoing pion-Nucleon pair. An E2 photon will produce a P-wave pion, and so the mixing ratio of interest is usually written in terms of these photo-pion multipoles as E1+/M1+, the plus sign referring to the spin of the excited state as being 1 + 1/2, or 3/2. During the last 6 or 7 years there has been a flood of attempts to extract this mixing ratio from existing pion production data, and this has led to numbers that are anywhere from +4 to -6%. The problem with using the old data sets is the non-resonant backgrounds one has to deal with. The older experiments were never designed to try to accurately extract these small amplitudes. I'm going to show you some data from a new experiment at LEGS that was specifically designed to address this problem.

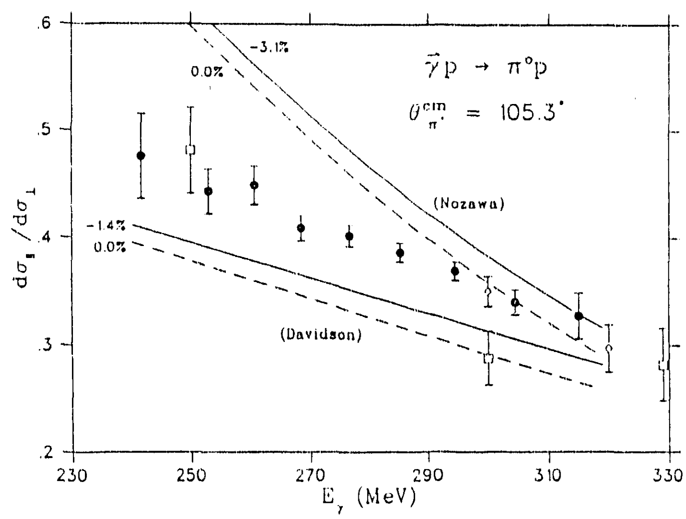
The reaction channel we will examine is neutral-pion production with polarized photons. The figure shows the ratio of two calculations for this reaction, as a function of angle, at 320 MeV which is near the peak of delta resonance[12]. In the calculation used for the numerator of this ratio, the resonant part of the E1+ multipole was asummed to be 3% of the M1+ amplitude. For the denominator, the resonant E1+ was set to zero. Whenever this ratio is different from unity there is a sensitivity to the E1+ component in the excitation of the delta. The dashed curve in the figure is what you would see with unpolarized photons. Over the range of angles that are convenient to measure, this ratio is around one, implying little or no sensitivity. The other two curves are labelled parallel and perpendicular according to the orientation of the linear polarization vestor of the proton. In the perpendicular geometry the ratio is again near 1, which reflects the fact that the perpendicular component dominates the unpolarized cross section. The parallel cross section, however, rises substantially above 1. Almost all of the sensitivity in this reaction comes from the parallel cross section. In fact, if we were to restrict yourself to only S and P wave pions, the perpendicular cross section near 90° would be completely independent of the E1+ multipole. This is a very convenient situation, since we can now form the ratio of the parallel and perpendicular cross sections. This parallel/perpendicular cross section ratio will display the sensitivity to the E1+ multipole, and at the same time cancel out most of the systematic experimental errors.



We will compare data on this cross section ratio to two recent models, both of which are rather sophisticated. So let us look at these in a little detail. The first is the work of Nozawa, Blankleider and Lee[12]. They calculate the contributions of the various diagrams for photo-pion production in a model that is both unitary and gauge invariant. Standard electromagnetic couplings are used to describe gamma-Nucleon-Nucleon vertices. The outgoing pion-Nucleon system is determined by the pion-Nucleon scattering phase shifts. Final state interactions between the outgoing pion and the Nucleon are explicitly taken into account. Only the gamma-Nucleon-delta vertex is parameterized. For this, three constants are used, a cutoff mass in the vertex form factor, and an electric and a magnetic coupling constant. The magnetic coupling constant is determined in comparisons with published M1+ multipoles. The E1+ multipole is decomposed into a "background" contribution, coming from all diagrams not involving a delta, and a Breit-Wigner resonance contribution. The electric coupling and the cutoff mass parameter are determined by requiring the coherent sum of these components to reproduce the isospin 3/2 E1+ multipole, as taken from the literature. Final adjustments to the parameters are made by comparing the predicted pion photoproduction observables with data. Using the Berends and Donnachie photo-pion multipoles[13], they obtain the best agreement with data for a mixing ratio of -3.1%

The second model that we will compare with is the work of Davidson, Mukhopadhyay and Wittman[14]. Their approach differs in that they impose Watson's Theorem, in which the photo-pion amplitude is written as a real part multiplied by an exponential containing the pion-Nucleon scattering phase shift. This theorem must hold as long as there is a unique exit channel, which implies that the photon energy is below the 2-pion production threshold of 309 MeV. To extract the part of the E1+ multipole associated with the delta requires decomposing the amplitude into resonant and background components. This decomposition is not unique. One method first suggested by Olsson is to write the amplitude as a coherent sum of Watson-like background and resonant amplitudes, with an extra phase in the exponent of the resonance part that is used to account for interference with the background. This extra phase is determined in a fit to published photo-pion multipoles, with the fit constrained in such a way that the total amplitude satisfies Watson's theorem. Final state interactions in the outgoing pion-Nucleon channel are not explicitly treated, but the requirement of Watson's Theorem essentially guarantees that they are implicitly included. Using the same set of Berends and Donnachie multipoles, Davidson et al. deduce an E1+/M1+ mixing ratio of -1.4%, about half the value deduced by Nozawa et al.

Let us now look at the ratio of the parallel to perpendicular cross sections for neutral-pion production, and compare with these two calculations. New data from LEGS at 105° is plotted in the figure. These results are from two experiments using the same two detector systems used in the deuterium studies. The two measurements are in excellent agreement and have been merged into one data set. They are also in good agreement with a few earlier measurements made at Khar'kov[15]. The top curves in the figure are from Nozawa et al. The solid line is their calculation for -3.1% E2 admixture. The dashed curve is obtained by turning off the resonant part of the E1+ amplitude. Near the peak of the delta resonance, about 320 MeV, these curves are quite close to the data. However, they clearly have the wrong energy dependence, which implies that the backgrounds have not been treated adequately. The lower curves in the figure are from Davidson et al. The solid line is their result for a mixing ratio of -1.4% and the dashed curve is again obtained by turning off the resonant part of the E2 amplitude. These calculations exhibit the correct energy dependence, but they appear low. The same general trends are repeated at 122°, although there the sensitivity is reduced and the solid and dashed curves from both calculations are closer together.



If we take the fact that the Davidson calculations exhibit the correct energy dependence as a confirmation that the backgrounds are properly treated in this model, then a mixing ratio between -3.0% and -3.5% would put the full calculation in reasonable agreement with the new data. That would be a nice end to this story. However, there are two problems that remain to be addressed. First, if a different unitarization method is used to decompose the amplitude into resonance and background contributions, such as writing them as a sum of pion-Nucleon amplitudes (the K-matrix method) or as a sum of pion-Nucleon phase shifts (the Noelle method), then the energy dependence as well as the fitted E2 mixing ratio also change. Changing the unitarization method amounts to changing how the final state interactions are implicitely included. This is a complicated problem and there is always the worry that the apparent agreement of the Olsson method with the observed energy dependence might be fortuitous. The second problem shows up if we compare with data at far backward angles. At 150° there is no longer any sensitivity to the E1+ multipole and the dashed and solid curves, from both Nozawa and Davidson, are indistinguishable. Here, both calculations have about the right energy dependence, but both are above the data, even those of Davidson et al. This is most likely a reflection of the photo-pion multipoles used as input to these calculations. The ratio of the polarized cross sections at this angle is determined by the M1+ multipole, and the extraction of a small E1+ component through its interference with this dominant multipole will be affected by uncertainties in the dominant component. These uncertainties are evidently not as small as have been assumed. To address this problem, a new experiment is planned at LEGS which will determine the polarized cross section ratio as well as the associated multipole decomposition by measuring a large number of observables simultaneously, with only one overall systematic error.

In summary, the polarization degree of freedom provides a powerful tool for studies of Nucleon-Nucleon interactions as well as Nucleon structure. A great deal of work remains to be done, but with it comes the promise of interesting confrontations between theory and experiment.

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References

1. LEGS Collaboration, G. S. Blanpied et al., Phys. Rev. Lett. **67**, 1206 (1991).
2. A. M. Sandorfi et al., IEEE NS-30, 3083 (1983); C. E. Thorn et at., Nucl. Inst. Meth. **A285**, 447 (1989).
3. R. Machleidt, Adv. Nucl. Phys. **19**, 189 (1989).
4. R. Dubois et. al., Nucl. Phys., **A377**, 554 (1982).
5. R. A. Arndt, private communication; phase-shift analyses of January 1991.
6. G. S. Chulick et al., Phys. Rev. **C37**, 1549 (1988).
7. V. G. Gorbenko, et al., Nucl. Phys. **A381**, 330 (1982).
8. J. Arends, et al., Nucl. Phys. **A412**, 509 (1984).
9. P. A. Wallace, Ph.D. thesis, University of Glasgow, UK (1989).
10. K. R. Garrow, M.Sc. thesis, Queen's University, Canada (1991).
11. K. M. Schmitt and H. Arenhoevel, private communication, Extensions of Few Body Sys. **7**, 95 (1989); P. Wilhelm, W. Leidemann, and H. Arenhoevel, private communication, Extensions of Few Body Sys. **3**, 111 (1988).
12. S. Nozawa, B. Blankleider, and T.S.H. Lee, private communication; Nucl. Phys. **A513**, 459 (1990).
13. F. A. Berends and A. Donnachie, Nucl. Phys. **B58**, 378 (1973).
14. R. M. Davidson, N. C. Mukhopadhyay, and R. S. Wittman, private communication; Phys. Rev. **D43**, 71 (1991).
15. V. B. Ganenko, et al., Sov. J. Nucl. Phys. **23**, 162 (1976); A. A. Belyaev, et al., Sov. J. Nucl. Phys. **35**, 401 (1982).
16. E. DeSantis et al., Phys. Rev. **C34**, 413 (1986); P.Levi Sandri et al., Phys. Rev. **C39**, 1701 (1989).

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