A major purpose of the Technical Information Center is to provide the broadest dissemination possible of information contained in DOE's Research and Development Reports to business, industry, the academic community, and federal, state and local governments.

Although a small portion of this report is not reproducible, it is being made available to expedite the availability of information on the research discussed herein.

LA-UR

CONF-880356--9

Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36

LA-UR--88-2918

DE89 000380

TITLE SUMMARY TALK--INTERNATIONAL CONFERENCE ON SPIN OBSERVABLES OF NUCLEAR PROBES

AUTHOR(S). Gerald T(homas) GARVEY

SUBMITTED TO To be preinted in Proceedings.
North-Holland Physics Publishing Division of
Elsevier Science Publishers B.V.
Amsterdam, The Netherlands

Los Alamos

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

MASTER

SUMMARY TALK—INTERNATIONAL CONFERENCE OF SPIN OBSERVABLES OF NUCLEAR PROBES

Gerald T. GARVEY

Los Alamos National Laboratory, MS H836, Los Alamos, New Mexico 87545*

A selected summary of the presentation and discussions at the 4th Telluride Conference is presented. The summary deals mainly with the effects of nuclear spin and isospin on the interaction between nucleons and their consequences in nuclear structure.

1. INTRODUCTION

I have been asked by several people if I had prepared this summary talk before coming to the Conference. Unfortunately, I am no longer in such close contact with this field that I could pretend to have created a presummary. As today was such a nice day, I could not resist skiing and so the more appropriate question is, "Am I prepared at all?"

Before launching into the summary, a few sociological observations are in order. I see new, young faces and hear new voices at this conference; happily, many of them are young women. It has taken far too long for us to obtain extensive participation of women in physics. This new development is most welcome and bodes well for the future. Being joined by Soviet colleagues once again is another excellent development at this meeting, welcomed by all of us. The even better news in this regard is that U.S. and Soviet scientists are not just attending meetings together but are jointly working together on real physics projects using the effective strengths of our two societies to carry out significant experiments. At Los Alamos we have joined with a very strong Soviet group at the Institute for Nuclear Study (INS) in Moscow to carry out a measurement of the low-energy solar neutrino flux using Ga. I see that the Argonne group is to work on internal polarized targets at the electron accelerator at Novisibirsk. It is very important to continue working to further these collaborations. It will not be simple as the bureaucracy on both sides is still uneasy with the notion. However, with some hard work the obstacles will be overcome and science will remain in the vanguard of international relationships.

2. SUMMARY

Although I did not come to Telluride with the summary talk to hand, I did come expecting to learn about the following questions.

* Work performed under the auspices of the U.S. Department of Energy.

2.1 *Where has the $\sigma\tau$ cross section gone?*

2.2 *Why is the longitudinal structure function in (e, e') quasielastic scattering only 60% of the Coulomb "sum rule?"*

2.3 *Why is the ratio of the (p, p') quasielastic cross section for longitudinal to transverse polarization approximately unity independent of A and ω?*

2.4 *How close is the correspondence between the (p, n) and (n, p) cross sections and corresponding weak interaction processes?*

2.5 *Where are the "antinucleons" in the nucleus?*

Not surprisingly, given the organizers of the conference and its history, much of the conference was devoted to these questions. I will try to summarize what has taken place over the past four days by dealing with these questions and recalling some physics presented here that was entirely new to me.

2.1 *Where has the $\sigma\tau$ cross section gone?*

Immediately following the discovery of the so-called giant Gamow-Teller (GT) resonance $(\sigma\tau^{\pm})$ via its large yield at 0° in p, n charge exchange it became abundantly clear that the observed yield for the process was well below the sum rule for the operator

$$+\beta^{-}_{GT} - \beta^{+}_{GT} = \frac{1}{3}(N - Z) \quad .$$

A variety of explanations sought to explain the observed deficiency such as the strength being transferred up to delta energies because at the quark level both GT transitions and the formation of a delta ($T = 3/2$, $S = 3/2$) involve change of the spin and isospin projection of a quark. Other, less exotic explanations argued the depletion of strength as arising from the two-body tensor force which simply spreads the strength to somewhat higher energies, thereby rendering it difficult to observe. The contribution of two-step processes, meson exchange effects, etc., are all believed to be far too small to account for the 40% shortfall in the observed yield. Two experimental tacts have been taken to address the question as to where the missing strength might be. One employs polarized beams and measures the spin of the outgoing particle so that the transferred spin can be inferred. This might be a sensitive way to find small pieces of the spin-flip strength. The other tact is to measure the (n, p) cross section to determine the β^{+}_{GT} term. In earlier discussions it was assumed to be zero and as it must be a positive definite quantity, this quantity can only make the spin flip deficit more severe. Let me first discuss the spin transfer measurements.

The spin-flip probability S_{NN} is defined as

$$S_{NN} = \frac{\sigma^{+-} + \sigma^{-+}}{\sigma^{++} + \sigma^{+-} + \sigma^{-+} + \sigma^{--}} = \frac{\sigma^{+-} + \sigma^{-+}}{\sigma}$$

where the first superscript indicates the incident particle spin projection and the second the spin projection of the outgoing nucleon. An examination of the matrix elements involved leads us to expect

$S_{NN} \approx 0$ for natural parity giant resonances ($\Delta S \approx 0$);

$S_{NN} \approx 0.5$ for $\Delta S = 1$ giant resonances;

$S_{NN} \approx 0.25$ for quasifree NN due to approximately equal parts of $\Delta S = 1$ and 0.

Kevin Jones presented data on S_{NN} measurements from p, p' forward angle inelastic scattering at 318 MeV on several nuclei. Figures 1 and 2 show the data from ^{40}Ca and ^{90}Zr,

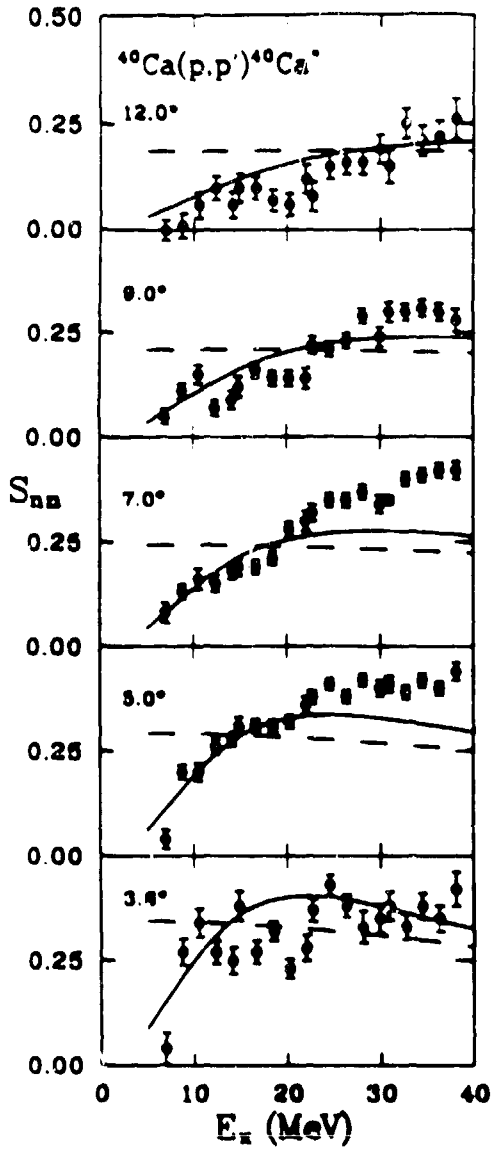

FIGURE 1

The spin-flip amplitude for inclusive quasielastic (p, p') scattering from ^{40}Ca at E_p = 319 as a function of residual excitation energy in ^{40}Ca for different scattering angles. The dashed line is the isospin averaged free nucleon-nucleon S_{nn} value, while the solid line represents a slab model response function value for S_{nn}.

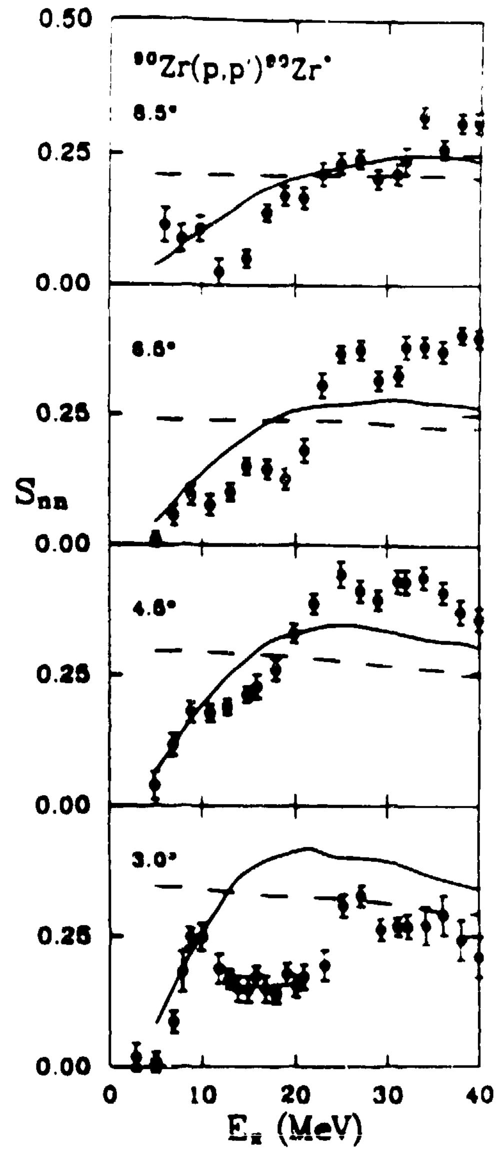

FIGURE 2

The spin-flip amplitude for inclusive quasielastic (p, p') scattering from ^{90}Zr at E_p = 319 as a function of residual excitation energy in ^{90}Zr for different scattering angles. The dashed line is the isospin averaged free nucleon-nucleon S_{nn} value, while the solid line represents a slab model response function value for S_{nn}.

both showing rather similar behavior. At small energy transfers to the nucleus the value of S_{NN} is near zero and gradually increases up to a value the order of 0.25, the value expected for quasifree scattering. At scattering angles between 4.5 and 7.5° where the momentum transfer is larger, there appears to be a larger value of S_{NN} at excitation energies in excess of 20 MeV. The explanation for this is likely the relatively larger role of the $\Delta S = 1$ giant resonances with $L = 1, 2$. This conjecture is supported by theoretical work reported on in this conference by R. Smith as well as detailed response function calculations carried out by Boucher and Wombach. The $\Delta S = 0$ yield is brought down to lower excitation energy by collective effects relative to the yield for $\Delta S = 1$. This leaves the $\Delta S = 1$ yield dominant at $E_x > 20$ MeV. and $q \approx 0.5$ fm^{-1}. This turn of events makes it difficult for polarization transfer measurements to be especially helpful in uncovering small pieces of the $L = 0$, $S = 1$, $\Delta T = 1$ strength unless the $\vec{p}, \vec{n}$ charge exchange yields are much simpler to interpret. They may well be, as there is no isoscalar collectivity to obscure the spin-flip character.

Another interesting feature of (p, p') calculations reported on by R. Smith is the necessity of requiring distortion in the initial and final scattering states to account for the yield of final-state excitation above 35 MeV. The yield corresponding to these energy losses, shown in Fig. 3, seems not to be due to two or more step processes and would not occur in the plane-wave limit.

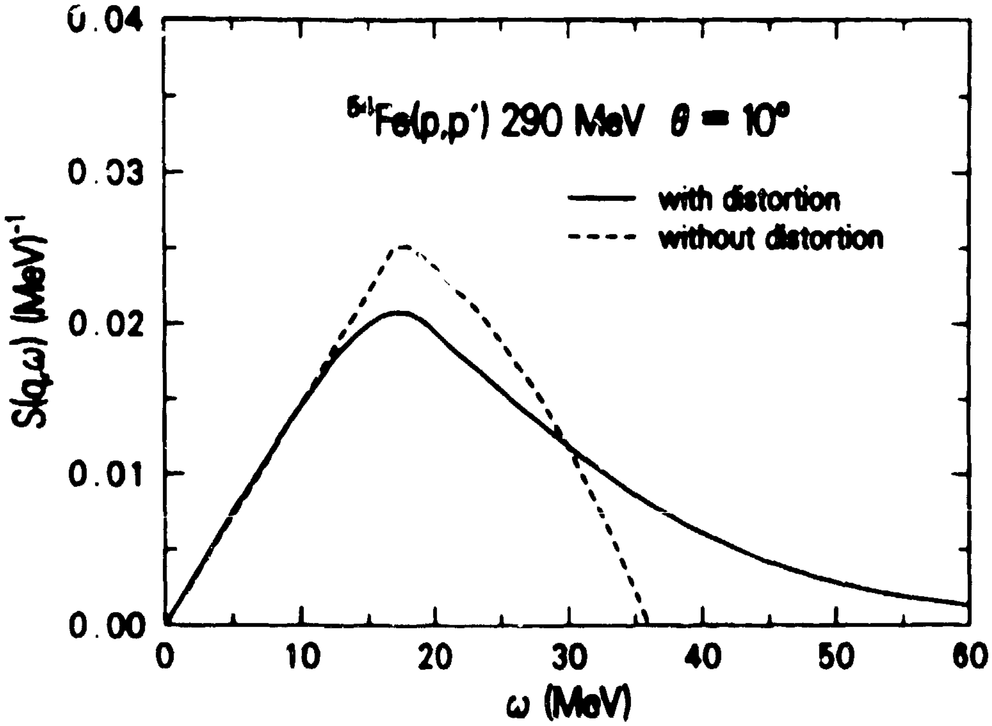

FIGURE 3

Calculation of the energy transferred in a quasielastic (p, p') collision as a function of the energy transfer. The figure shows the important role played by distortion in allowing higher energy transfers.

Peter Jackson presented some beautiful data from TRIUMF on n,p charge exchange. The data were taken at 460-MeV neutron energy on ^{9}Be, ^{13}C, ^{54}Fe, ^{90}Zr, and ^{208}Pb. The ^{54}Fe(n,p) data were very impressively fit with a set of $L = 0$, 1, and 2 multipoles, Fig. 4. An interesting feature of these measurements on ^{13}C$(n,p)^{13}$B ($T = 3/2$ g.s.) is that it yields a value of 10.97 ± 0.56 mb/sr for the Gamow-Teller unit cross section compared to the analogous ^{13}C$(p,n)^{13}$N ($T = 3/2$, 15.1 MeV) reaction of 14.7 ± 1.1 mb/sr. This discrepancy is interesting and should be resolved as it is difficult to see how it can be fundamental; most likely there is a mistake lurking somewhere in this result, or else there is a very nasty isospin violation. Jackson said very little about the impact of the Fe, Zr, and Pb measurements on the sum rule, presumably because it is again difficult to measure the $L = 0$, $\Delta S = 1$ yield at energies above the "Gamow-Teller" resonance.

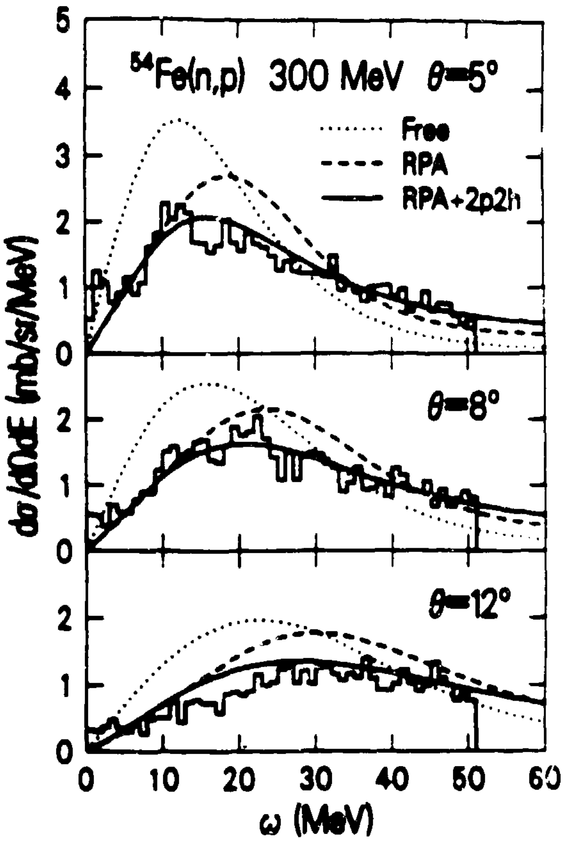

FIGURE 4
The (n,p) spectrum from ^{54}Fe at $E_n = 300$ MeV. The histogram is the actual data, while the dotted line is free n,p scattering. The dashed line is RPA with $\Delta L = 0, 1, 2$, while the solid line includes the $2p$-$2h$ correlation in addition to RPA.

2.2 Why is the longitudinal structure function in (e,e') quasielastic scattering only 60% of the Coulomb "sum rule?"

One of the puzzling results challenging our simple picture of the nucleus is the failure to find the Coulomb sum rule in the longitudinal structure function. In a simple and apparently naive picture, the inclusive longitudinal structure function for quasielastic electron scattering when integrated over excitation energy should count the number of protons in the target nucleus. In the lightest nuclei, this sum rule is realized, but in nuclei as light as ^{12}C the integrated structure function falls short of the total charge. In heavier nuclei only 60% of the sum rule (Z) is observed. Strangely enough, the transverse structure function, which is more complicated, appears to be near the predicted value. This situation is depicted in Fig. 5 where the ratio of the transverse to longitudinal structure function is shown. The ratio should be $\mu_{p/1} = 2.79$, but because the longitudinal structure function is less than expected, this ratio appears to be more nearly 3.5. There are many discussions that ascribe this deficiency to two-body correlations, but while this may put some at ease, I find it absolutely unconvincing. It seems that every major difficulty in nuclear structure calculations failing to produce experimentally observed rates is ascribed to

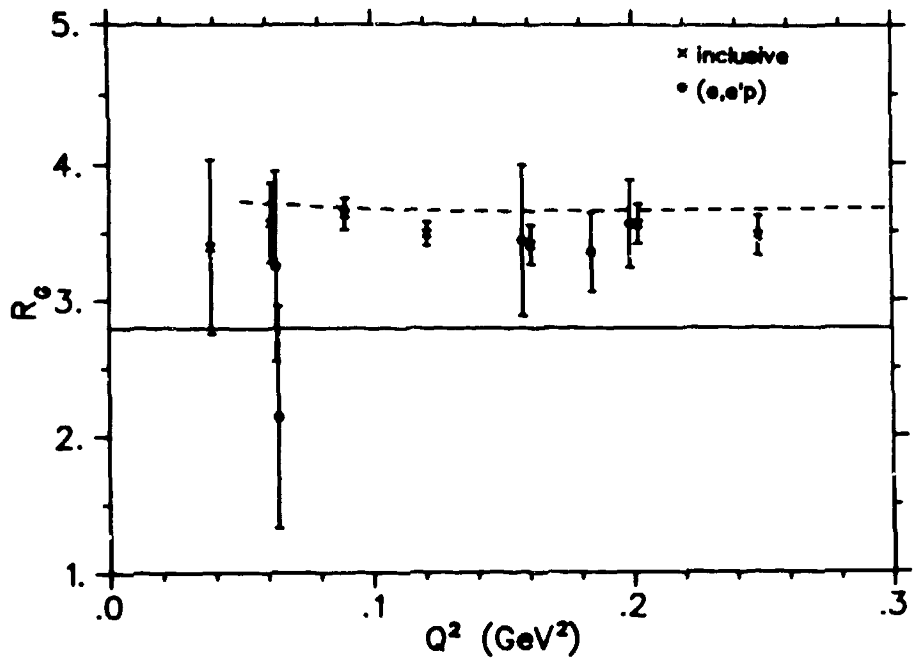

FIGURE 5
Ratio of the $F_T(Q^2)/F_L(Q^2)$ for (e,e') inclusive and (e,e',p) as a function of Q^2. In the latter case one would expect the ratio to be the ratio of the proton magnetic moment (2.79) to the proton charge (1).

two-body correlations, but whenever experiments to measure these correlations are carried out, they escape detection. To my mind, this shortfall of the longitudinal structure function is just another example of missing yield relative to what one expects from the present phenomenological description of nuclei as interacting neutrons and protons. There is likely something very seriously wrong with that picture. If it indeed is the case that short-range correlations shift a larger fraction of the simple wave function hundreds of MeV above the ground state, then the picture of orderly, well-behaved nucleons moving in shell-model orbitals is simply an artifact of convenience having little to do with reality. It must be the case that these strong effects do not materially affect the regularities observed in the observables associated with low-lying states other than the fact that absolute rates are never correctly predicted. However, there may be several major modifications to this simple picture. This issue should be resolutely pursued and squared with a less phenomenological description of the structure of nuclei.

2.3 Why is the ratio of the (p,p') quasielastic cross section for longitudinal to transverse polarization approximately unity independent of A and ω?

The longitudinal ($\underset{\sim}{\sigma}\cdot\underset{\sim}{p}$) and transverse ($\underset{\sim}{\sigma}\times\underset{\sim}{p}$) responses of a nucleus in proton quasielastic scattering are expected to be quite different. The strongly attractive p-wave pion-nucleon coupling was believed by some theorists to be sufficiently attractive to bring about pion condensation in the nucleus at an appropriate density. On the other hand, the repulsive nature of the ρ-nucleon coupling appears to thwart the formation of the pion condensate. The pseudoscalar nature of the pion is manifest in the longitudinal coupling ($\underset{\sim}{\sigma} \cdot \underset{\sim}{p}$) while the vector nature of the ρ requires that it show up in the transverse coupling ($\underset{\sim}{\sigma} \times \underset{\sim}{p}$). In finite nuclei, these modes are mixed but examination of the separated longitudinal and transverse modes were expected to reveal the underlying roles of π and ρ exchange on the nucleon-nucleon interaction as modified by the nuclear medium. That is, the longitudinal mode should appear stronger relative to the transverse mode at moderate momentum and energy transfers.

Thus, the expected ratio of the longitudinal $[R_L(q,\omega)]$ to transverse $[R_T(q,\omega)]$ response functions at fixed q as a function of ω is shown by the dotted curve in Fig. 6. In the $(\vec{p}, \vec{p}\,')$ quasielastic scattering the effect is diluted because the scattering is a mixture of $T = 0$ and $T = 1$ interaction. The above discussion pertains only to the $T = 1$ amplitudes; however, the effect was still believed to be readily discernible.

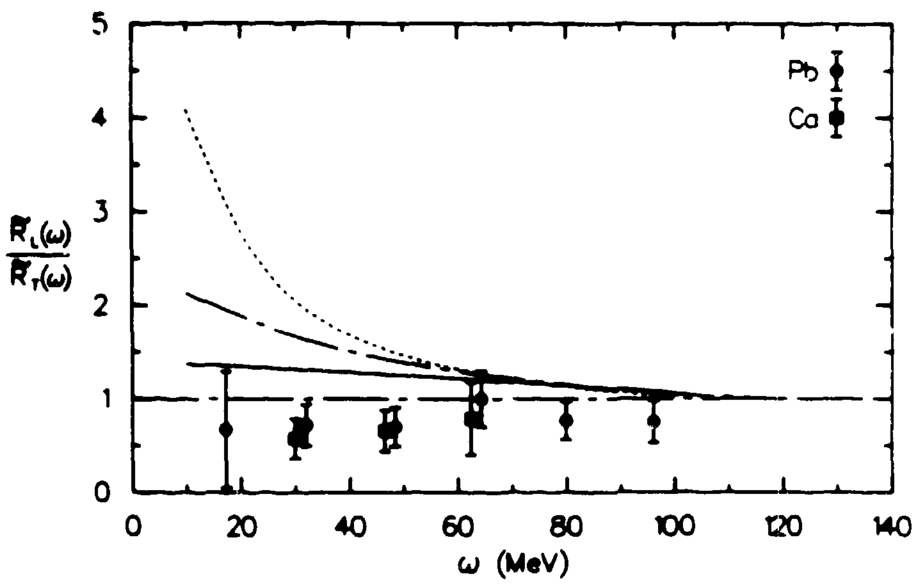

FIGURE 6
Ratio of the ratio of the longitudinal response of quasielastic scattering in Pb and Ca to ^2H to the same ratios for the transverse response. The ratio of these ratios is plotted as a function of the residual excitation energy in the final nucleus. The experiments were carried out at $q = 1.8\ \mathrm{fm}^{-1}$.

Recall that earliest EMC data showed an excess at small x ($x < 0.25$) for the quark distribution function per nucleon in deep inelastic scattering from Fe as compared to deuterium. Many theorists attributed this excess as arising from the pion exchange processes within nuclei. Hence, these same theorists were surprised to see that the ratio of the ratio of the longitudinal to transverse structure functions of Pb to ^2H as a function of energy is constant and very near 1. Some have interpreted this as evidence for a lack of pion excess in nuclei; however, there are several reasons why any energy dependence in this ratio of the ratios should be suppressed in (p,p'). First, as mentioned above, the scattering proceeds via both $T=0$ and 1 amplitudes, thus there is a dilution of the effect being sought. Next, adsorption tends to keep contributions to this channel in the nuclear surface and, lastly, the finite size of the nucleus tends to mix the longitudinal and transverse modes. All these considerations tend to wash out the effect, though most calculations leave residual effects that should be observable.

Experimentally, for the future one can do little except measure the same quantities in $\vec{p},\vec{n}$ quasielastic-elastic where the scattering will be pure isovector and re-examine the issue when these data are in hand. The newly installed NTOF system at LAMPF, in conjunction with a new high-intensity polarized ion source (OPPIS), will be crucial to this program.

2.4 How close is the correspondence between the (p,n) and (n,p) cross sections and corresponding weak interaction processes?

We now come to the relationship between the (p,n) and (n,p) cross sections and the rates for the corresponding charge-changing weak processes. The correspondence arises from the nuclear initial and final states being the same for the strong and weak processes. There is no *a priori* reason to expect any relationship except that the matrix elements involved appear similar at the level of the nonrelativistic impulse approximation involving nucleons only. As there has been no theoretical formulation of the role of meson-exchange currents in the strong charge exchange reactions, it is difficult to formulate a very penetrating analysis. It is known that the effects of meson exchange are usually small in the case of allowed weak transitions that proceed at near full strength. That is, they are less than 1% of an *unhindered* Fermi or Gamow-Teller transition. Effects arising from finite binding in analogous states are much more serious, as witness the difference between the GT transitions ${}^{12}\mathrm{B} \rightarrow {}^{12}\mathrm{C} + \beta^- + \tilde{\nu}_e$ and ${}^{12}\mathrm{N} \rightarrow {}^{12}\mathrm{C} + \beta^+ + \nu_e$. Isospin invariance would lead one to expect that ft values of these transitions would be equal. The observed 10% difference is attributed to the nearly unbound nature of the last proton in ${}^{12}\mathrm{N}$. Although this is most likely correct, quantitatively calculating the size of effect is *very* difficult. This difficulty, of course, does not occur in the issue at hand as the initial and final states are common, but the weak process senses the entire nuclear volume while the strong charge exchange process $\{(p,n),(n,p)\}$ is much more sensitive to the nuclear wave function at the nuclear surface because of adsorption effects in the incident and outgoing channels.

As there is no theoretically well-founded description of the strong scattering process, there is no alternative at this time but to compare the observed weak decay rates and corresponding charge exchange cross sections. Terry Taddeucci and his collaborators have done that in a rather extensive manner as we heard in the previous talk this evening. They define a "unit cross section," $\hat{\sigma}_\alpha(E_p,A)$, via

$$\sigma_\alpha \exp(E_p,A,q,\omega) = \hat{\sigma}_\alpha(E_p,A)F_\alpha(q,\omega)B_\alpha$$

where $\sigma_\alpha(\exp)$ is the experimentally measured p, n cross section at 0° for a transition α which is either Fermi or Gamow-Teller. B_α is the square of the matrix element measured via weak decay which equals

$$B_{GT} \equiv \frac{1}{2J_i + 1} |\langle J_f, A \parallel \sigma\tau^- \parallel J_i, A\rangle|^2$$
$$B_F = \frac{1}{2J_i + 1} |\langle J_f, A \parallel \tau^- \parallel J_i, A\rangle|^2 \quad .$$

$F(q, \omega)$ is a factor depending on the momentum (q) and energy (ω) transfer and

$$\underset{q \to 0, \omega \to 0}{F(q, \omega)} \to 1 \quad .$$

These cross sections show a decrease with A for both Fermi and Gamow-Teller transitions. The decrease is ascribable to distortion and absorption.

One of the interesting outcomes of this study is the dependence on incident proton energy of the relative sizes of Fermi and Gamow-Teller cross sections. Fig. 7 shows the results obtained for ^{14}C over a range of energies. ^{14}C is a very good case for study, as the F and GT transitions are pure and well separated. The curious fact is that the square

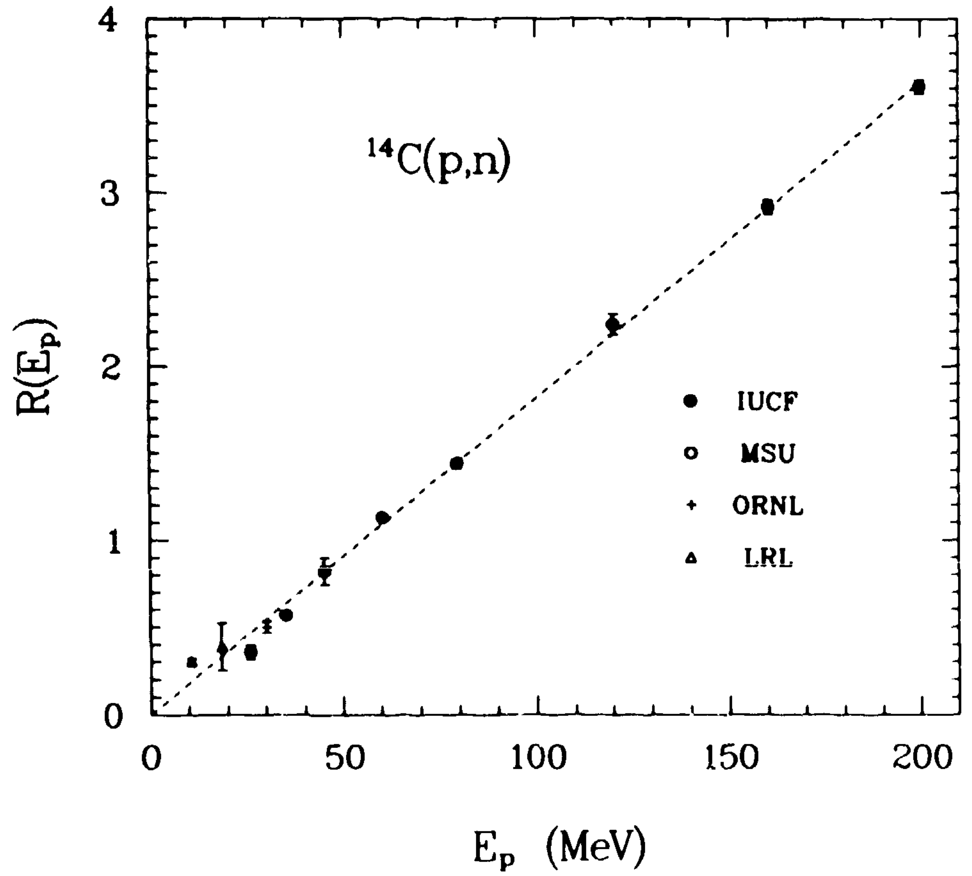

FIGURE 7

Ratio of the square root of the cross section at 0° of the "Gamow-Teller transition" to the "Fermi transition" in $^{14}C(p, n)^{14}N^+$ as a function of proton energy. The dotted line is $R(E_p) = E_p/55$.

root of the GT to F yield as a function of energy falls on a straight line [$E_p/55$ (MeV)] for $55 \le E_p \le 200$ as shown in Fig. 7. This very interesting fact is partially understood at a more fundamental level and is due largely to a reduction in the two-body V_τ. The density dependence has also been shown to be very important. Love and collaborators have recently worked out a G-matrix approach based on the Bonn potential. The density dependence of the G matrix for the various effective couplings is shown in Fig. 8. A great deal of progress has been made and is being made in this area, but improvement by factors of 2 to 5 is needed in the quantitative understanding and the evaluation of reliability if charge exchange is to provide the matrix elements so badly needed in other areas of nuclear physics investigations.

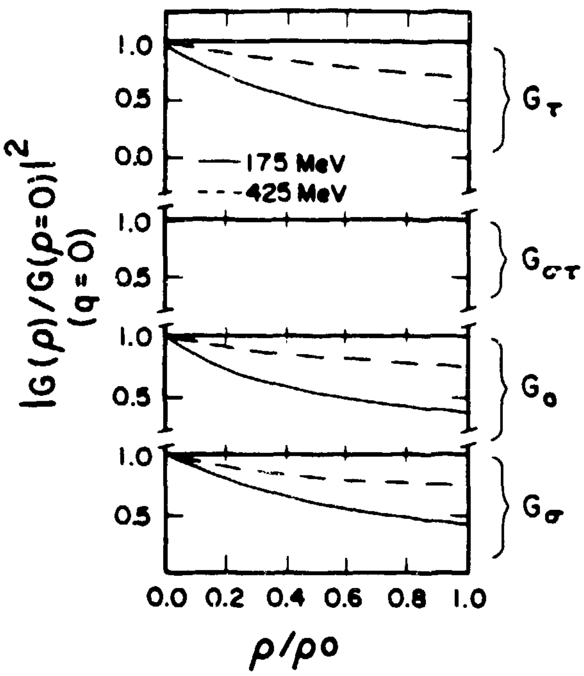

FIGURE 8
Plot of the density dependence of the various effective two-body interactions in nuclei as a function of density. The value 1 represents the density of nuclear matter.

2.5 Where are the "antinucleons" in the nucleus?

Unfortunately, this still remains a theoretical issue with there being no supporting experimental data. The commonly used relativistic formulation of the nucleon-nucleus interaction with its very attractive scalar and repulsive vector fields leads to a considerable reduction in the nucleon-antinucleon energy gap in the nucleus. The gap is roughly halved to ~400-500 MeV. It is by no means clear how to uncover the increased antinucleon presence that the gap reduction would predict. Deep inelastic scattering, or Drell-Yan, experiments will not produce convincing, if any, evidence for $\overline{N}$ in nuclei. It seems important to demonstrate the reduced gap if we are to have real faith in the present day relativistic formulation. At the present moment, the contact is entirely through certain spin-dependent effects that are obtainable more naturally in a Dirac formulation than via any known nonrelativistic prescription. The rest of the baggage that comes with the relativistic formulation is very difficult to deal with. I certainly take my hat off to those few strong souls who are re-establishing all of nuclear structure in a relativistic description. They are few, and the job is enormous.

In a global sense, establishing a nuclear theory in terms of a finite number of hadronic types that will work up to energy and momentum transfer of a few GeV would be a great achievement because one could then employ QCD to push on to higher energy. We would then have a way of proceeding from low energy up to the TeV scale.

3. NEW MATERIAL

Among the new material presented at this conference, the report by Roy Holt on photodisintegration of the deuteron done at NPAS and the two reports on delta production by Ellegard and Dimitriv were most interesting to me.

Let's start with the deuteron photodisintegration. The experimental result is a result of a collaboration between Argonne/Caltech/NPAS referred to as NE8. To predict the behavior of the expected form factor at large momentum transfer, there are several ways to proceed. In the context of the parton model at asymptotically large Q^2, it is necessary for the struck quark to share its momentum with the remaining quarks; each of these quark-quark interactions introduces a factor of $1/Q^2$ due to hard gluon exchange. In the case of the deuteron, this involves five quarks in addition to the one that is struck to take up the momentum so that at very large Q^2 we expect that the deuteron form factor would scale as

$$F_d(Q^2) \underset{Q^2 \to \infty}{\sim} Q^{-10} \quad .$$

At lower than asymptotic Q^2 a more detailed model is required. One commonly used procedure is to simply calculate the cross section with a hadronic model that includes all the known hadron dynamics and form factors. Alternatively, Brodsky and collaborators have set up an ansatz based on QCD that produces a scaling behavior well below where one would expect scaling to work. In their approach, the nucleons share equally in the momentum transfer and are correlated via a gluon exchange. While the correctness of these assumptions can be easily called into question, it provides a specific recipe that often agrees with experiment and leads to what is often referred to as precocious scaling because it sets in long before one would expect any scaling behavior based on QCD. In this case, one would have for the matrix element in deuteron photoabsorption

$$M_{\gamma d}^{(Q^2)} \sim Q F_d(Q^2) \sim Q\, F_N^2(Q^2/4) \frac{1}{Q^2}$$

where the last factor of $1/Q^2$ accounts for the gluon exchange between the nucleons. As $F_N(Q^2) \underset{Q^2 \to \infty}{\longrightarrow} Q^{-4}$, the predicted behavior shows the same power law dependence as the predicted behavior shows the same power law dependence as the asymptotic case when $Q^2 \to \infty$. In a hadronic description, one has nucleon form factors for the photon adsorption and the momentum is shared via pion exchange so that the matrix element has the following form

$$M_{\gamma d} \approx Q\, F_N(Q^2)\, F_{\pi N N}^2(Q^2) \frac{1}{Q^2} \quad .$$

As $F_{\pi N N}^2(Q^2)$ goes as $[\frac{\Lambda^2}{\Lambda^2 + Q^2}]$ there are clearly differences at finite Q^2.

In a model-independent format the cross section for $D(\gamma, p)n$ at large E_γ is written as

$$\frac{d\sigma}{d\Omega} = \frac{1}{S}\, F_p^2\, F_n^2\, \frac{f(\theta_{cm})}{P_T^2}$$

where $f(\theta_{cm})$ is an energy-independent "reduced" amplitude. The task of any model would then be to compute $f(\theta_{cm})$. Figure 9 shows the observed yield for as a function of photon energy as reported by the NE8 collaboration. Above 0.8 GeV their results appear to agree much better with the predictions of chromodynamics than with the specific meson exchange model shown in the figure. However, caution is the order of the day as meson exchange calculations are often very model dependent. It is, however, another interesting example of apparent precocious scaling.

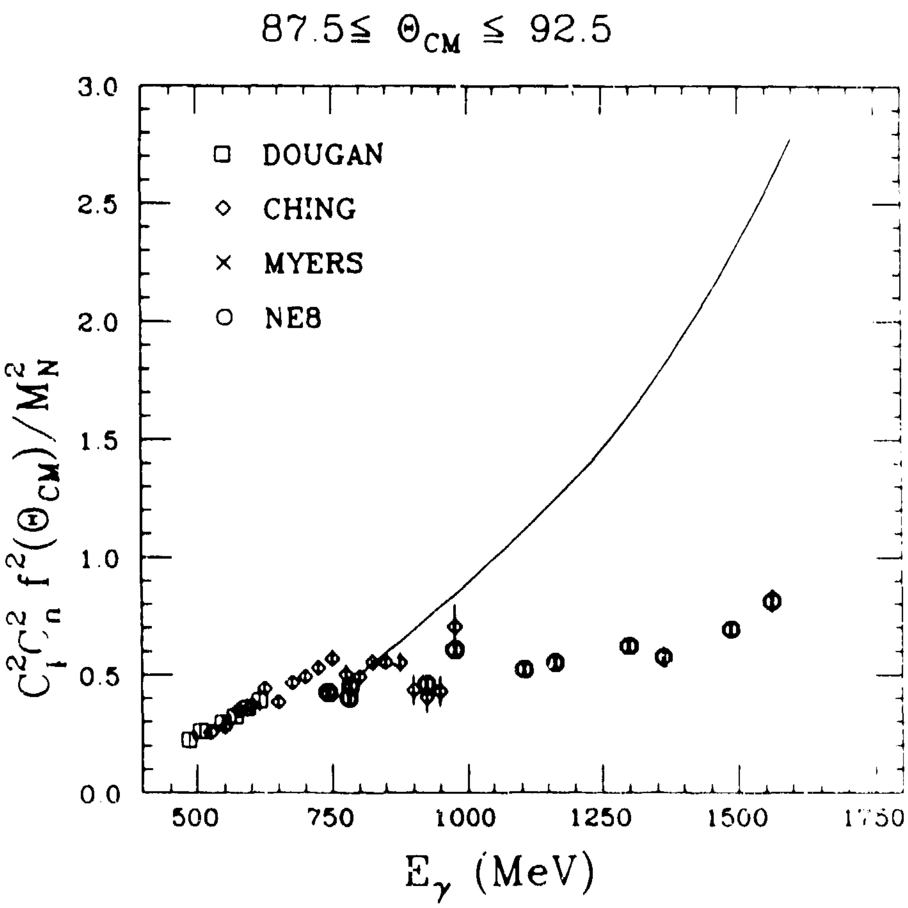

FIGURE 9
Plot of the photodisintegration cross section of the deuteron as a function of incident photon energy.

Delta production is a further example of the $\sigma\tau$ operator and several interesting presentations were made regarding delta production with complex projectiles on nuclei. The reports by Dimitriv and Ellegard on delta production as seen via charge exchange reactions at Dubna and Saterne, respectively. The Dubna experiments involve $P(^3He,t)\Delta^{++}$ and $^{12}C(^3He,t)X$. These experiments were carried out at ^3He incident momenta of 4.40, 6.81, and 10.79 GeV/c. The observed 0° cross sections at 6.81 and 10.79 GeV/c bombarding energy are shown in Figs. 10(a) and (b). The cross section for this process seems large, for example, at 10.79 GeV/c the yield from a ^{12}C target at 0° is about 85 mb/sr, a factor of two above the yield on a free nucleon. The measured polarization is roughly one half of

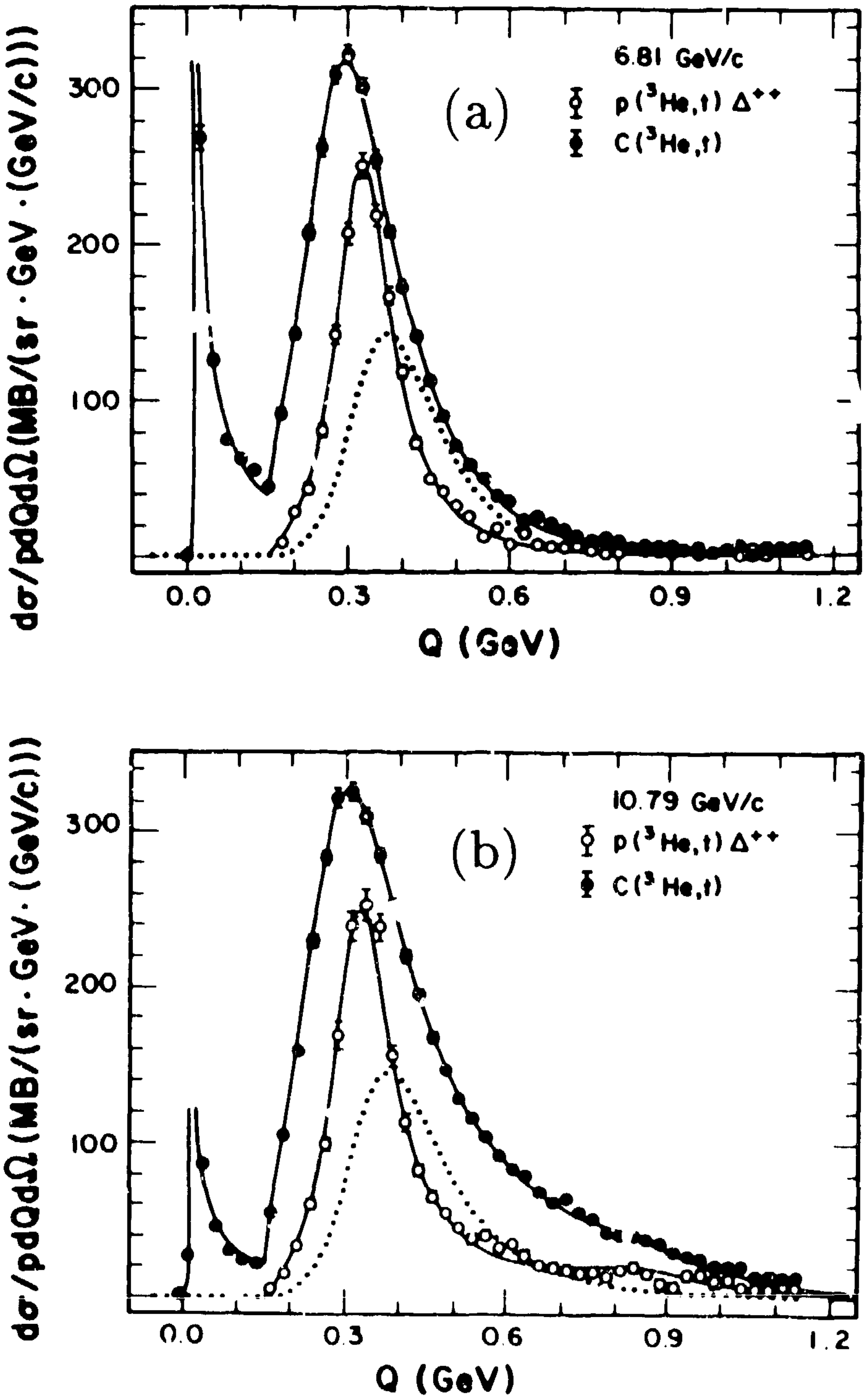

FIGURE 10

(a) Plot of the triple differential cross section for the (^{3}He,t) reaction at 0° for $P_{^3\mathrm{He}}$ = 6.81 GeV/c. The cross section is plotted as a function of residual excitation energy in the target system. (b) Plot of the triple differential cross section for the (^{3}He,t) reaction at 0° for $P_{^3\mathrm{He}}$ = 10.79 GeV/c. The cross section is plotted as a function of residual excitation energy in the target system.

what would be expected from delta production via pion exchange. Hence, half the cross section must be due to other processes, possibly ρ exchange. Dimitriv asserts that there are two processes involved in Δ production. One is quasifree Δ production with the Δ being produced in the continuum. The other process involves the creation of the Δ in the field of the nucleus. Processes of the first kind can be readily identified via observation of the normal products of Δ decay in coincidence measurements. The peak resulting from coincidence measurement occurs at higher energy than does the Δ inclusive spectrum. Hence, the noncoincident contribution is at lower energy and is reminiscent of a Δ-hole excitation in the nuclear system, supporting Dimitriv's assertion.

The Saterne measurements are carried out using 0.900 GeV/amu heavy-ion beams and involve proton charge changing processes via (He,t), (^{16}O,^{16}N), (^{20}Ne,^{20}F), and also a case of neutron charge exchange in the beam via (^{20}Ne,^{20}Na). The first three reactions leave behind Δ^+ or Δ^{++} in the target nucleus while the last reaction leaves Δ^0 or Δ^-. The peak associated with charge exchange production of Δ^+ and Δ^{++} shows a downward shift of the delta resonance peak in C that is some 70 to 80 MeV below the free production and then as a function of A the peak position remains relatively fixed in energy, while the charge exchange producing Δ^0 and Δ^- yields a peak that shows a continuous downward shift. These effects must represent the combined effect of Coulomb plus nuclear binding effects on the delta in nuclei. This is schematically shown in Fig. 11. The size of these delta production cross

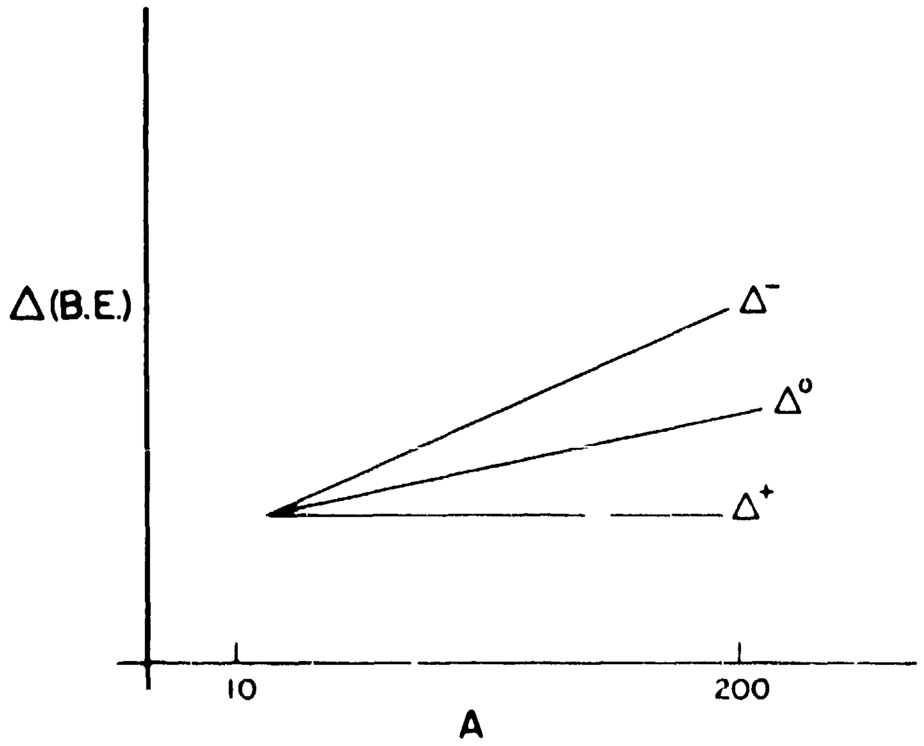

FIGURE 11
Schematic plot of the apparent binding energy of various charged states of the Δ in nucleon systems as a function of A. The binding energy increases upward.

sections is again very large and would be larger if the giant GT resonance occurred as a bound state in the outgoing projectile. It is likely that the total Δ production cross section is on the order of hundreds of millibarns.

4. CONCLUSION

There were a host of new experimental undertakings reported on in this meeting that were once thought too difficult to carry out. There is genuine progress in what we are able to both consider and execute. For example, the tensor polarization T_{20} in electron elastic scattering on the deuteron, (n,p) reactions, $(\vec{p},\vec{n})$ are now being carried out. We will soon be gathering data on $\vec{A}(\vec{p},\vec{p})$, $A(\vec{p},\vec{n})$, $(e,e',\vec{p})$, and (e,e',n). Spin-dependent deep inelastic scattering, as well as neutral current elastic scattering should reveal much about the partonic structure of the nucleon. All of these experiments require extensive effort and a high degree of effective collaboration. They represent the kind of effort that the nuclear physics of tomorrow will require.

This has been an excellent meeting. We should thank Chuck Horowitz and Charles Goodman for creating a 4th Telluride Conference that retains all the vitality and importance of the preceding conferences!