DIBARYON RESONANCES

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ABSTRACT

Phase shift analyses of pp elastic scattering indicate resonance-like loops in several partial waves, which could be attributed to exotic 6-quark resonances or simply to inelastic threshold effects. Differences between theoretical predictions and experimental spin correlations in the pion-deuteron and γ-deuteron channels have been cited as evidence for resonances, but no unambiguous partial wave analyses are available in these channels. The nucleon-nucleon dibaryon candidates are coupled predominantly to the $NN\pi$ channels, and theoretical interpretation of these effects will require detailed understanding of the $NN \to \Delta N$ reaction.

INTRODUCTION

The spectroscopy of dibaryons, baryonium, and gluonium appears to have some common features. Theoretically these states involve degrees of freedom not present in the $Q\bar{Q}$ or Q^3 spectra. Experimentally the interest in these states has been spurred by striking evidences, such as the S(1930) in $\bar{p}p$, the $\iota(1440)$ in J/Ψ decays, and the $^1D_2$ and $^3F_3$ resonance loops in pp elastic scattering. In each case considerable effort has gone into searches for similar phenomena in other processes, but these efforts have generally not resolved the central issues, and there is still no firm proof that new degrees of freedom other than $Q\bar{Q}$ and Q^3 are needed. The separation of $Q^2\bar{Q}^2$ or gluonium states from ordinary $Q\bar{Q}$ mesons is still replete with difficulties; observation of $\bar{p}p$ decay modes or coupling to radiative J/Ψ decays represents only circumstantial evidence. And while the 6-quark nature of dibaryon channels may be trivially obvious, the separation of interesting dibaryon resonances (QCD bound states of 6 quarks) from ordinary hadronic effects (inelastic threshold effects or virtual bound states of two baryons) will require considerable experimental effort and theoretical insight. In this report we will concentrate on the coupled-channel effects seen in pp scattering, which we regard as the central evidence for dibaryons. We will briefly review the effects seen in the γD, πD and I-0 NN channels, which may or may not be connected with resonances.

RESONANCES IN $pp \to pp$

The $^1D_2$, $^3F_3$, ($^3P_2$, $^1G_4$ . . ?) "resonance" spectrum seen in elastic phase shift analyses exhibits several peculiarities (notation: $^{2S+1}L_J$). First, the ground states have $J = 2,3$ . . whereas by analogy with baryon and meson resonances, one might

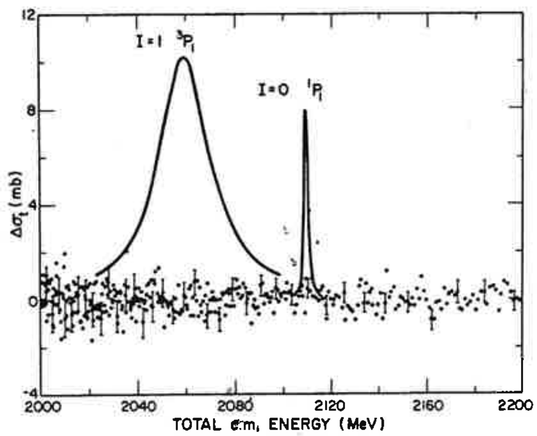

Fig. 1. σ_{TOT}(np) with smoooth background subtracted, from Ref. 2.

expect low-lying $J = 0, 1$ ($^1S_0$, $^3P_0$, $^3P_1$) states[1]. If these states were low enough in mass, they would be mainly elastic and would show up as clear peaks in σ_{TOT} (pp, np), given by the unitarity bound

$$\sigma^J_{TOT} = \frac{2\pi}{k^2}(2J+1)\frac{\Gamma_{el}}{\Gamma_{TOT}} \qquad (1)$$

A recent precision measurement of σ_{TOT} (np), illustrated in Fig. 1, provides stringent limits on the existence of such states[2]. Other searches for low-mass structure, for example a recent study of the asymmetry in pd → pX [3], have also proved negative.

A second issue concerns the absence so far of convincing evidence for strange partners. Searches for S = 1,2 dibaryons in the reactions $K^-d \to K^+X$, $K^-d \to \pi^+X$, and $\pi^-d \to K^+X$ by the Rome-Saclay-Vanderbilt group[4] have revealed no structures other than the well-known Λp (2130) state, which is most likely a virtual bound state of the ΣN system, analogous to the deuteron[5]. Similarly, stringent limits have been placed on low-lying S=2 states in $pp \to K^+K^+X$ [6]. In fairness, the search for strange dibaryons has been confined to bump hunts, and there have been no systematic Λp or Σp phase shift analyses, which would be sensitive to broader structures.

The third notable feature of the $^1D_2$, $^3F_3$ . . states is their dominant inelastic decay. Regarded as Breit-Wigner resonances, the branching ratios have Γ_{el}/Γ_{TOT} <15%. The measured inelastic cross sections indicate that the remaining $^1D_2$ and $^3F_3$ decays are into the NNπ channel, including <15% couplings to the πd channel (the πd channel is presumably produced via final-state interaction from the NNπ intermediate state[7]; with or without resonances, one would expect the πd production to be only a fraction of the NNπ cross section). Thus, the large inelasticities suggest that the resonances may be just reflections of the partial wave thresholds in NΔ production[8]. A more subtle feature that is worth emphasis is the following: in theoretical calculations of the partial wave amplitudes in NN → NΔ, the waves expected to have the largest inelastic cross sections are precisely the $^1D_2$ and $^3F_3$ waves[9]. This feature is trivial for the $^1D_2$ wave, since it is the only wave that can produce the final state NΔ in an S wave by the transition $pp(^1D_2) \to N\Delta(^5S_2)$. However, this is not trivial for the $^3F_3$. There are several amplitudes that can feed the NΔ final state in an overall P wave, and pion exchange leads naturally to enhancement in the transition $pp(^3F_3) \to N\Delta(^5P_3)$. Similarly the $pp(^1G_4)$ wave is naturally expected to dominate D-wave NΔ production. Thus, the large inelasticities observed in the $^1D_2$, $^3F_3$ and $^1G_4$ waves are natural consequences of the helicity structure of pion exchange. The phase variations seen in the elastic partial waves may be more difficult to explain, although they would follow naturally from bound states in the NΔ channel (see below).

The data base for pp elastic scattering is quite extensive up to 800 MeV. New experimental results presented at this conference include a detailed mapping of the $\vec{p}\vec{p} \rightarrow pp$ spin correlations from 400 to 600 MeV by the Sin-Geneva group[10], and new measurements of $\Delta\sigma_T$ by the Saclay Group[11]. Energy dependent and independent phase shift analyses have been carried out up to 1000 MeV[12,13,14,15]. The region above 800 MeV is still problematic, and there appear to be significant differences between the Arndt-Verwest[12] and the Saclay[16] phase shifts in this region. The principal pp → pp elastic partial wave amplitudes are shown in Fig. 2, where the main discrepancies between the two analyses are exhibited. The waves that rotate counter clockwise with increasing energy are the highly inelastic

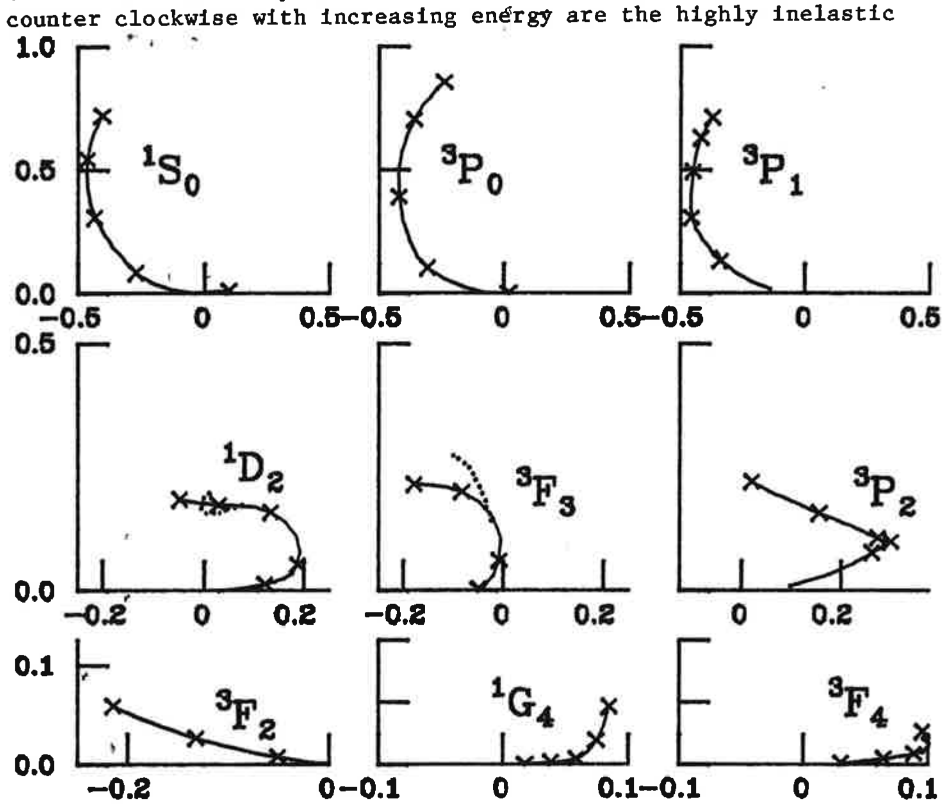

Fig. 2. Argand plots for dominant elastic amplitudes (mixing terms not shown) from Ref. 12. Crosses denote kinetic energies 0.2, 0.4, 0.6, 0.8, and 1.0 GeV. Dotted trajectories for $^1D_2$ and $^3F_3$ are 0.7-1.0 GeV from Ref. 16.

$^1D_2$, $^3F_3$, $^3P_2$, $^3F_4$, and $^1G_4$. We emphasize that the phase shift analyses provide an accurate summary of the elastic observables and total cross sections below 1000 MeV, including structures which have sometimes been adduced as evidence for dibaryons (e.g., the narrow structure in A_{NN} (90°) near 700 MeV[17] and the broad enhancement in $k^2(A_{NN}-A_{LL})d\sigma/d\Omega$ (90°) around 600 MeV[18]). Thus, the evidence regarding dibaryons is entirely contained in the Argand plots of Fig. 2.

Historically the spin-dependent total cross sections $\Delta\sigma_L$ and $\Delta\sigma_T$ provided evidence for structure in the forward amplitudes[19]. At present, there are several sets of measurements of $\Delta\sigma_L$ and $\Delta\sigma_T$ which are mutually consistent at the 15% level below 1000 MeV[20]. We find that the phase shift solutions give a good interpolation of these data. Fig. 3 shows the decomposition of $\Delta\sigma_L$ and $\Delta\sigma_T$ into elastic and inelastic contributions. This decomposition was first given by Arik and Williams[21], and their conclusions are essentially consistent with newer data. $\Delta\sigma_T$ is almost entirely due to the inelastic channels (mainly $^1D_2$) above 400 MeV. The structure in $\Delta\sigma_L$ is also due to the inelastic contributions; the peak at 600 MeV and the dip at 800 MeV are reflections of the $^1D_2$ and $^3F_3$ inelasticities respectively. There is a large elastic component in $\Delta\sigma_L$ due to the $^1S_0$, $^3P_0$ and $^3P_1$ waves. A similar analysis using the Saclay phase shifts has been carried out by Bystricky et. al.[16]. A more direct way of looking at the structures associated with the inelastic channels is given in Fig. 4, which displays the contributions to the total cross section from the principal inelastic transitions; for clarity, we have indicated schematically the NΔ inelastic final states that are expected to dominate.

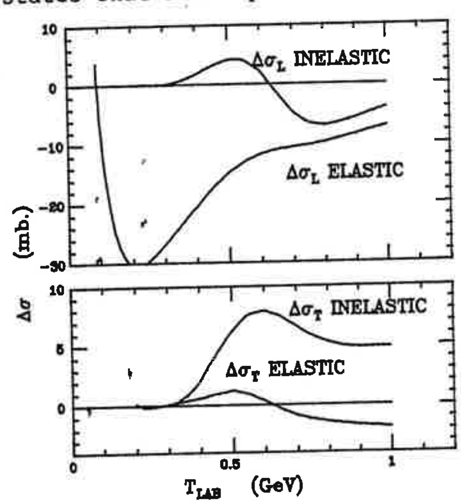

Fig. 3. Decomposition of $\Delta\sigma_L$, $\Delta\sigma_T$ into elastic and inelastic contributions, from the phase shift analysis of Ref. 12.

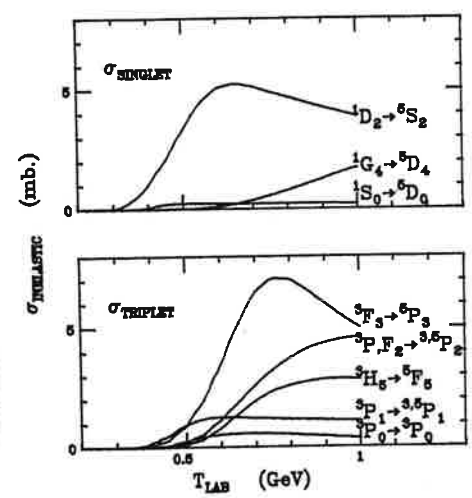

Fig. 4. Inelastic partial wave cross sections from the inelasticities of Ref. 12; expected ΔN final states are indicated.

It is clear that the coupling between the NN and NΔ channels is pivotal in understanding the dibaryon structures. In terms of a coupled-channel partial-wave S matrix

$$S(\eta,\delta_1,\delta_2) = \begin{bmatrix} \eta e^{2i\delta_1} & i(1-\eta^2)^{1/2}e^{i(\delta_1+\delta_2)} \\ i(1-\eta^2)^{1/2}e^{i(\delta_1+\delta_2)} & \eta e^{2i\delta_2} \end{bmatrix}, \qquad (2)$$

the elastic phase shift analysis (and likewise any measurements of elastic or inelastic total cross sections in pure spin states) is sensitive only to the parameters δ_1 and η for each wave, and not the $N\Delta \to N\Delta$ phase shift δ_2. Given only δ_1 and η we could construct quite different Argand plots for the channel $N\Delta \to N\Delta$, as illustrated in Fig. 5; the difference between the resonant and nonresonant NΔ solutions in Fig. 5 lies in the behavior of δ_2.

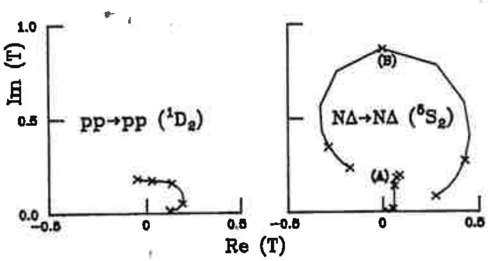

Fig. 5. The $^1D_2$ pp → pp Argand plot, and two possible NΔ → NΔ Argand plots consistent with the $^1D_2$ inelasticity. Solution (A) has slowly varying δ_2; (B) has Breit-Wigner behavior for δ_2.

A true coupled-channel Breit-Wigner resonance of the type seen for example, in πN scattering, would cause a 180° advance in an eigenphase of the S matrix[22]. For a two-channel process, this would imply a 180° advance in $\delta_1+\delta_2$, which happens to coincide with the phase of the inelastic transition NN → NΔ. We note that several analyses have been carried out using potential model and K-matrix representations, to fit the full S matrix and extrapolate the amplitudes into the complex energy plane[23,24,25,26]. Since the phase δ_2 is unknown, these analyses suffer an inherent continuous ambiguity. Although these analyses generally find poles which could correspond to Breit-Wigner resonances, NΔ virtual bound states, or migrated t-channel singularities, none of the solutions exhibited by Edwards and Thomas[23] or by Verwest[25] yield a net 180° phase advance in $\delta_1+\delta_2$. This is not because such solutions do not exist (Fig. 5, curve B, providing a trivial example), but because they were not compatible with the particular representations used.

As noted above, the inelasticities of the partial waves can be understood qualitatively by unitarized π-exchange models, and much effort has gone into explaining the waves in terms of threshold effects, without explicit Breit-Wigner resonances. Consider a thumbnail sketch of the origin of resonant/nonresonant solutions (Ref. 27 provides a more exhaustive analysis). If dibaryon interactions were mediated by meson exchanges, with N,Δ, and mesons being the only "elementary" particles in the theory, then the only interesting phenomena would be NN, NΔ . . . bound states. Levinson's theorem[28] prescribes that the phase shift associated with a stable bound state (e.g., the $^3S_1$ wave in np → np) should decrease by 180° with increasing energy. A virtual bound state could be formed by strong attractive forces in the NΔ system, which would be free to decay into the open pp channel. Examples of such states are the Λp (2130)[5], the Y*(1405)[29], and the S*(980)[30]. An NΔ virtual bound state would act like a resonance in the pp channel (phase advance), and a bound state in the NΔ channel (phase retreat), with no net phase advance in $\delta_1 + \delta_2$; in terms of Levinson's theorem, the net phase change is zero because the bound state is unstable. A Breit-Wigner resonance, on the other hand, corresponds to a particle that is just as "elementary" as N and Δ, for example an exotic color-bound state $Q^3_{8C} - Q^3_{8C}$. By Levinson's theorem, such a resonance, being unstable against decay into the NN and NΔ channels, would cause a 180° advance in $\delta_1 + \delta_2$.

To achieve practical realization of these different behaviors, we can use a K-matrix formalism, with

$$T^{-1} = K^{-1} - i\rho \tag{3}$$

where ρ are the channel momenta, and the elements of K correspond approximately to the Born terms. With only meson exchanges in the NN and NΔ channels, the K-matrix elements would be smooth in energy (no poles in s). However, the unitary T matrix can have poles in s due to the behavior $\rho_2 \to i|\rho_2|$ below effective threshold in the NΔ channel (threshold is smeared by the Δ width). These virtual bound state poles give Breit-Wigner behavior in the pp channel and a stationary phase $\delta_1+\delta_2$ above NΔ threshold; the requirements for this behavior are strong pp → NΔ couplings (K_{12}), and strong attraction consistent with a bound state in the NΔ channel (large K_{22}). This is the kind of solution considered by Edwards and Thomas[23]. Other methods of unitarizing the meson-exchange Born terms contain basically the same physics as the K-matrix approach, producing resonance loops in pp → pp, due to the strong pp → NΔ → pp intermediate state[31]. To incorporate a genuine exotic resonance such as our hypothetical color-bound state, there are two possible changes in the K-matrix representation: (1) add an explicit pole $g/(s_R-s)$ to the K-matrix elements to describe the extra Born term, or (2) add a third channel, $Q^3_{8C}-Q^3_{8C}$, which is closed by color confinement ($\rho_3 \to i|\rho_3|$), so that the resonance appears in the NN and NΔ channels as a virtual bound state of channel 3. Either description gives coupled-channel Breit-Wigner behavior and 180° phase advance for $\delta_1+\delta_2$.

The Breit-Wigner behavior expected for the exotic resonance case could be nullified by the Jaffe-Low compensation mechanism[32,33]. It is also unclear that a description involving extra exotic channels such as $Q^3_{8C}-Q^3_{8C}$ can be made consistent[34]. In any case, with only the elastic amplitudes and no data on $\delta_1+\delta_2$, the physical interpretation is ambiguous. Analyses have been carried out with color exotics[35,36], and also with only mesonic exchanges in the NN and NΔ channels[37,38,39,40] which reproduce the qualitative features of the pp elastic amplitudes.

Experimental information on the inelastic channels, which is needed to obtain δ_2, is regrettably sparse. For $pp \rightarrow \pi^+ d$ there exist recent spin correlation measurements from the SIN-Geneva group below 600 MeV[41], and there have been many new measurements of the single-spin asymmetry parameter from threshold to 1200 MeV[42,43,44,45,46]. For the dominant inelastic channels, there are new bubble chamber measurements of unpolarized cross sections and density-matrix elements for $pp \rightarrow pn\pi^+$ and $pp \rightarrow pp\pi^0$ from 500 to 1200 MeV[47]. Single spin asymmetries have been measured for the $pp\pi^0$ and $pn\pi^+$ final states at LANL at 650 and 800 MeV[48], and at the Argonne ZGS for $pp \rightarrow pn\pi^+$ from 600 to 1200 MeV. The ZGS experiment was designed to cover the full phase space for production and decay of the Δ^{++}; typical results are shown in Figs. 6 and 7 for Δ^{++} density-matrix elements, to illustrate the quality of the data. Some spin correlation measurements have been carried out on $pp \rightarrow pn\pi^+$ at TRIUMF (380 to 515 MeV)[49] and at LANL at 800 MeV[50,51]. We emphasize that the objective of any program of inelastic measurements should be to obtain the $NN \rightarrow NN\pi$ partial wave amplitudes, analogous to the very fruitful work done in the past decade on baryon resonance

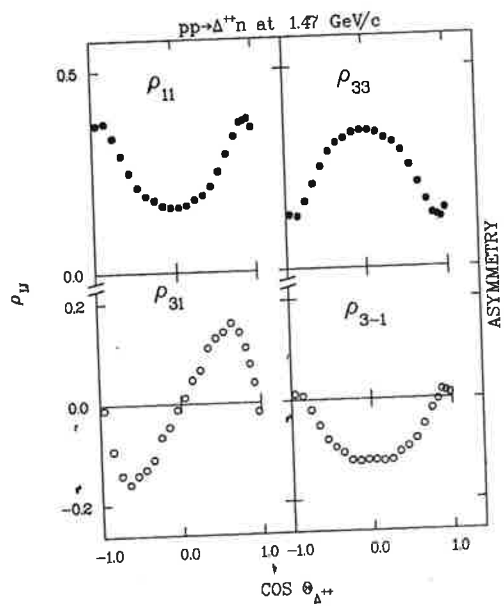

Fig. 6. Preliminary unpolarized density-matrix elements at 806 MeV for $pp \rightarrow \Delta^{++}n$ from the ZGS experiment; $1.18 < M_{p\pi^+} < 1.28$ GeV.

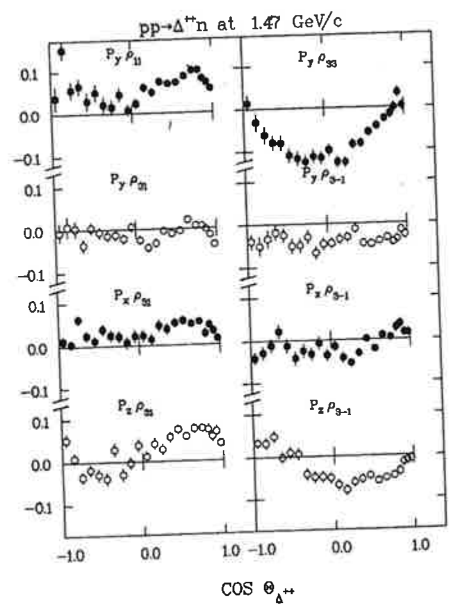

Fig. 7. Preliminary dependence of the Δ^{++} density matrix elements on beam polarization, out of the scattering plane (P_y), in the scattering plane (P_x), and longitudinal (P_z).

couplings in $\pi N \to \pi\pi N$. Such partial wave analysis can be augmented by the knowledge of the inelasticity parameters from the elastic phase shift analyses, and by the $pp \to \pi^+ d$ measurements. We stress that there is little physics justification in measuring the inelastic contributions to $\Delta\sigma_L$ and $\Delta\sigma_T$, since these quantities depend only on the inelasticity parameters which are already "known", and not on the inelastic phase shifts δ_2, which are the quantities needed for resonance analysis.

Much theoretical effort has gone into understanding the $pp \to \pi^+ d$ data[52,53,54]. This channel should reflect the behavior of the intermediate $NN\pi$ state, and so in effect it is the structure of the $NN \to NN\pi$ amplitudes which these models are testing. It is well documented that the model predictions for the $pp \to \pi^+ d$ asymmetry fail above 600 MeV; this is illustrated in Fig. 8. In Fig. 8 we have also shown the asymmetry for the reaction $pp \to pn\pi^+$, extrapolated to the region of phase space close to np threshold from the ZGS experiment. The agreement is quite good (note that this extrapolation is very crude and does not project out the np ($^3S_1$) wave). Fig. 9 shows the asymmetry around 90° from several experiments, together with the extrapolated asymmetries from TRIUMF and ZGS data for the free $pp \to pn\pi^+$ reaction. The free and bound asymmetries are in good agreement. Note that the extrapolation to np threshold projects out a tiny part of the ΔN phase space, especially at higher energies; away from this region of phase space, the asymmetry in $pp \to pn\,\pi^+$ becomes strongly negative for T>800 MeV. It would seem remarkable for any theoretical model to predict the overall asymmetries in $pp \to pn\pi^+$, let alone the behavior in the pn threshold corner of phase space. In fact, Niskanen's predictions

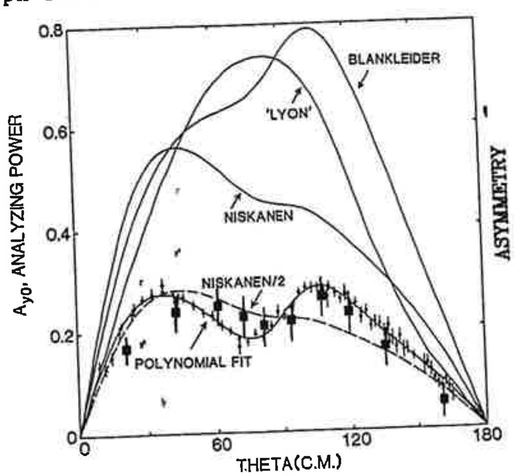

Fig. 8. Asymmetry in $pp \to \pi^+ d$ from Ref. 44, with various theoretical predictions. Solid boxes are extrapolations to pn threshold from $pp \to pn\pi^+$.

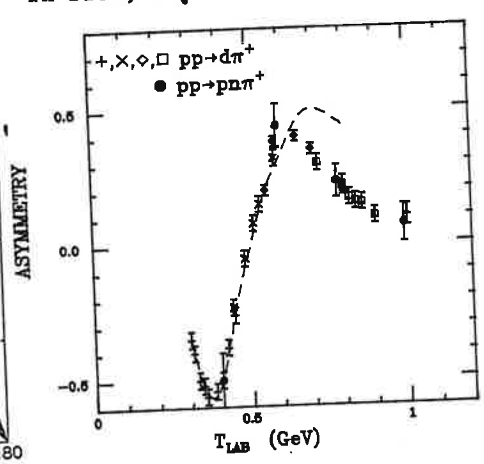

Fig. 9. Asymmetry in $pp \to \pi^+ d$ at 90°. From Ref's. 42-46. Solid boxes are extrapolations from $pp \to pn\pi^+$. Theory curve is from the predictions of Ref. 52.

are quite good up to 600 MeV (dashed curve in Fig. 9). The negative asymmetry at low energies is related to elastic $\pi^+p \to \pi^+p$ polarization, and is caused by interference of the amplitudes for production of S and P wave $N\pi$ systems in $pp \to pn\pi^+$. At higher energies, the positive asymmetry is caused by interference between different partial waves for $pp \to \Delta N$, and these are highly model dependent. We conclude that the observables for $pp \to \pi^+d$ and $pp \to pn\pi^+$ are closely linked, as expected; unfortunately the π^+d data provides only a tiny window on the full $pn\pi^+$ reaction, and the latter is sensitive to the inelastic phase shifts which are needed to elucidate the resonance question.

I = 0 CHANNELS

The LANL total cross section measurements in the np channel,[2] illustrated in Fig. 1, have been used to obtain $\sigma_{TOT}(I=0)$, and to set limits on the elasticity of possible I=0 dibaryons. The $^1F_3$ resonance proposed by Hoshizaki[55] to explain $\Delta\sigma_L(I=0)$ data[50], would be incompatible with $\sigma_{TOT}(I=0)$; with Γ = 50 MeV, Lisowski et. al. show x_e <0.05. It has been argued that the I = 0 channel is free of the complication of possible ΔN threshold effects, and is therefore a good place to look for genuine resonances. This argument is clearly fallacious if the I=0 states have <5% elasticity; either such resonances do not exist, or they exist only in the inelastic channels and will not be seen in $np \to np$.

Physically, the absence of the πd and ΔN channels from I=0 suggests that the inelastic I=0 cross sections must be small below NN* threshold. The inelastic I=0 cross section can be expressed as

$$\sigma(I=0) = 2\sigma_{INEL}(np)-\sigma_{INEL}(pp) \tag{4}$$

and this can be further decomposed into[57]

$$\sigma(I=0) = \frac{1}{3}\sigma_1(I=0)+\frac{2}{3}\sigma_2(I=0) \tag{5a}$$

$$\sigma_1(I=0) = 6\sigma(np\to np\pi^\circ)+3\sigma(pp\to pp\pi^\circ)-3\sigma(pp\to pn\pi^+) \tag{5b}$$

$$\sigma_2(I=0) = 3(\sigma(np\to NN\pi^\pm)-\sigma(pp\to pp\pi^\circ)) \tag{5c}$$

where $\sigma_1 = \sigma_2 = \sigma(I=0)$ by isospin conservation[57]. Arndt and Verwest[58] have fitted the available channel cross sections and found that $\sigma(I=0)$ is indeed quite small below 1000 MeV (e.g. $\sigma(I=0)$<1mb at 800 MeV). The contribution σ_1 in Eq. 4b is poorly determined, because it depends on differences of large cross sections and because the channel $np \to np\pi^\circ$ is measured only below 600 MeV. Extraction of σ_1 from the available data by Lehar et. al.[57] suggested that $\sigma_1 \gg \sigma_2$ (i.e., isospin violation), but it is clear that better data are needed. There are recent data that can be used to obtain a fairly accurate estimate of σ_2, as shown in Fig. 10[47,59]. If σ_2 is taken to be the inelastic I=0 cross section, then even more stringent limits can be placed on the elasticity of a resonance. For example,

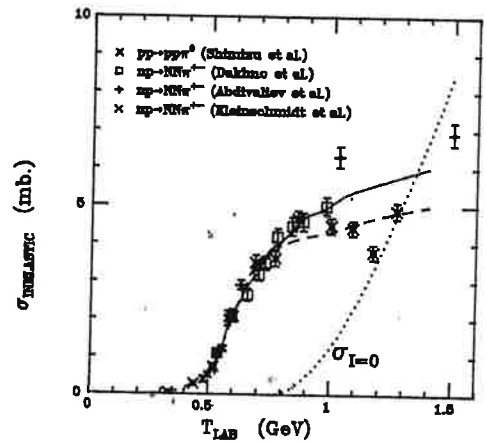

Fig. 10. Total inelastic cross sections from Ref's 47 and 59, and fitted I=0 cross section (Eq. 4) from Ref. 58.

if $\sigma_2 < 1$ mb, then a $^1F_3$ resonance at 800 MeV would have $x_e < .02$. Conversely, any I=0 dibaryon should show up as a huge effect in the $np \rightarrow pp\pi^-$ channel.

DIBARYONS IN $\gamma d \rightarrow np$

The photoproduction reaction has been extensively searched for evidence for dibaryons, and we refer the reader to Schwille's review[60]. To summarize, present theories are unable to predict the detailed behavior of cross sections or single spin asymmetries in this reaction. These theories are quite complicated, involving many Born term contributions. The disagreements can be patched up by introducing "dibaryon resonance" amplitudes ad hoc, but this fix is certainly not unique. At this conference new results on the incident photon asymmetry were presented by the Yerevan group[61]. Not surprisingly, these data bear no resemblance to published predictions with or without resonances. There appears to be little or no prospect for obtaining Argand plots for this reaction.

DIBARYONS IN $\pi^+d \rightarrow \pi^+d$

The situation in $\pi^+d \rightarrow \pi^+d$ is somewhat more interesting, owing to the observation of oscillations in the vector and tensor polarizations with energy and angle[62,63]. We refer the reader to the reviews presented at this conference by Mathie and Grüebler for more details on the experiments and their interpretation.

As noted above, the cross section data on $pp \rightarrow \pi^+d$ alone guarantees that the $^1D_2$, $^3F_3$. . .branching ratios into π^+d are less than 15%. The same conclusion can be drawn from the absence of a large backward peak in $\pi^+d \rightarrow \pi^+d$ [64]. With no resonances, the Glauber model predicts substantial amplitudes in the π^+d S,P,D, and F waves, which arise from the convolution of the deuteron form factor and the coherent $\pi^+p+\pi^+n$ elastic amplitudes[65]. The qualitative features of the vector polarizations are consistent with this model, eg positive peaking near 90° with negative-going polarization near the forward and backward regions. The oscillations require small departures from Glauber in one or more high L/J waves; small admixtures of waves with L=J+1, J=2,3, or 4 have been shown to give rise to oscillations[66,67], but no fits have yet quantitatively described the vector polarizations at all angles and energies[62]. It is not clear that these effects are in any way related to the J=2,3,4 structures in pp scattering, or whether they represent some other kind of deviation from Glauber.

The tensor polarization also exhibits strong oscillations in energy and angle around 135 MeV (near the $^1D_2$ peak in effective mass), according to the SIN experiment[63]. Neither the oscillations nor the magnitude and sign of the SIN tensor polarization are consistent with Glauber theory. We caution that the SIN results are at present altogether inconsistent with the LANL experiment published by Holt et. al.[68]. Thus it seems premature to speculate on the origin of the tensor polarization oscillations.

SUMMARY

It is the author's prejudice that systematic partial wave analyses of the NNπ channels are needed to settle the physical interpretation of the $^1D_2$, $^3F_3$ . . . "resonances". In the absence of such data, there is ample reason to believe that the dibaryons are just manifestations of strong attractive forces in the NΔ channel, rather than color-exotic objects. We suspect that this spirit of inconclusiveness will characterize dibaryons, baryonium, multiquarks, and gluonium for years to come.

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