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SUMMARY OF HYPERNUCLEAR SESSIONS *

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SUMMARY OF HYPERNUCLEAR SESSIONS

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Fifteen papers were presented in the four hypernuclear sessions. Since the Steamboat Springs meeting of two years ago, it is easy to discern a change in emphasis from nuclear spectroscopy to the question of possible quark clustering in nuclei. It is also obvious, and should be stressed, that hypernuclear studies, especially experimental ones, are presently severely hampered by a lack of suitable facilities and sufficient running time at existing accelerators. It is hard to be optimistic about significant amelioration of this situation in the near future.

The study of nuclei begins properly with the study of the simplest nuclear system; namely deuterium and its strangeness analogues, the Λ systems.

The first figure shows a missing mass spectrum of the Λp system from the Λ threshold to above the Σ -N threshold near 2130 MeV. The most striking feature here is the appearance of a large

Fig. 1. Invariant mass spectrum for (K^-, π^-) on deuterium in the Λp channel.

spike or a threshold cusp in the Λp spectrum very near the onset of Σ production. This has led to intense studies over the past few years by Dalitz and his collaborators. They interpret the spike as a final state interaction among the Λ , Σ , and N channels, as originally suggested by Rodberg and Karplus. At this meeting Torres presented a detailed analysis of the reaction using the Faddeev method and incorporating all the known two-body NN and YN potentials. The graph shows fits to the stopped kaon data of Tan. A satisfactory fit requires the introduction of a pole in the ΣN channel quite near to the Σ threshold, a state which could be interpreted as an SU_3 partner of the deuteron.

Of particular interest is the appearance of a shoulder on these data, near an energy of 2140 MeV, some 10 MeV above threshold. This shoulder has been suggested by Piekarz et al. as a candidate for a six quark state, an $S = -1$ dibaryon resonance.

The status of the searches for Jaffe's H -particle have already received some attention at this conference. However, it should be stressed that quark bag models also predict the appearance of narrow $S = -1$ states, at mass values near the Σ production thresholds. Sainio reviewed the status of the bag model predictions and pointed out that the presence of the s quark allows flavor representations of lower dimensionality in the

Fig. 2. Apparatus for the dibaryon search in (K^-, π^-) on deuterium. The range hodoscope allows emphasis in the Λ - p exit channel.

six-quark system, maximizing the color-magnetic attraction. The predictions thus lie below the thresholds for pion emission from these systems. Hence a strange dibaryon could be expected to be narrow and actually observable as a peak in the mass spectrum.

The data on the Brookhaven experiment of Piekarczyk allow the examination of the Λp channel in detail by a trick which suppresses the Σ exit channels. A deuterium target is surrounded by a range hodoscope which requires the detection of three charged particles in the final state--two from Λ decay and one from the proton partner (Fig. 2). The BNL experiment indicates the presence of this 2140 MeV peak and its p-wave character, which is demanded by the bag model predictions. There is no calculation based on the known two-body potentials which can produce this peak for the boson exchanges; hence it is apparently our best dibaryon candidate.

Phil Pile discussed planned dibaryon searches in future AGS experiments. The singlet partner of the triplet dibaryon just discussed would be predicted to be 40 MeV below the triplet--that is near 2100 if the 2140 candidate is indeed a dibaryon resonance. It could not be excited in (K^-, π^-) on deuterium because of the smallness of the spin flip amplitude. However, it could be seen in the (K^-, π^+) reaction on ${}^3\text{He}$, in a region distant from the complication of the Σ threshold and the attendant quasi-free Σ production. If this peak is seen in the experiment--scheduled for the fall of this year at the BNL hypernuclear

Fig. 3. Count rate predictions for two proposed H-particle searches.

spectrometer--I believe a very strong case can be made for the reality of this 6 quark cluster.

Pile also discussed suggested Λ -particle experiments. There are two varieties--the single target ${}^3\text{He}$ method and the two target method involving cascade production in hydrogen and a subsequent cascade-deuteron capture. An atomic state is formed which decays to the Λ --should it lie near the $\Lambda\Lambda$ threshold. Since this was discussed in the plenary session I will make only some general comments. The sensitivity of these experiments over the mass range is shown in Fig. 3. Both kinds of experiments require a separated kaon beamline operating near 1.8 GeV/c, and both experiments have been analyzed by Aerts and Dover who predict cross sections well within the kaon intensities provided by the AGS and the proposed line. Thus the results of these experiments, whether they are positive or negative, would provide a definitive test of the model prediction. It indeed would be a pity if these experiments--which are among the most significant test of the role of quarks in nuclei--could not be mounted at the AGS because of lack of funds for this line. The line could be called the 1-cent beamline--it could be built at a U.S. per capita cost of one penny.

Fig. 4. At left are shown CERN ${}^{12}\text{C}(\text{K}^-, \pi^+)$ data compared to quasi free calculations with a constant Σ production amplitude (solid line) and including the Y^* (1520) resonance (dashed line). At the right are shown the quasi free calculation for ${}^6\text{Li}(\text{K}^-, \pi^+)$ where the $\text{P}_{3/2}$ and $\text{S}_{1/2}$ hole strength distributions are accounted for.

Turning to that great mystery of hypernuclear spectroscopy--the observation of narrow Σ states--I need not repeat the arguments given earlier by Gal, who indicated that it is difficult to find a theoretical justification for narrow Σ states 80 MeV above the N threshold. There are several new and important bits of evidence concerning those states and one rather provocative suggestion.

It will be recalled that the observed Σ structures lie above Σ binding, where the quasi free sigma-production cross section rises rapidly. No bound Σ states have ever been observed. Kishimoto presented calculations of the quasi free Σ production by the pole graph method in which several important effects are included--namely the experimental momentum distribution from $(e, e'p)$, the effect of Y^* resonances, and the distribution of hole strength in the recoiling nucleus. The illustration, Fig. 4a, shows data from CERN at 400 MeV/c ($K^-\pi^+$) on ^{12}C and the quasi free calculation. Shown is the effect of including the Y^* resonance at 1520. Figure 4b shows a quasi free fit to $^6\text{Li}(K^-, \pi^+)$, BNL data at 713 MeV/c. The effect of the $P_{3/2}$ and $S_{1/2}$ hole strengths is indicated. It is clear that a proper calculation of

Fig. 5. A calculation of final state interaction peaks in $^{12}\text{C}(K^-, \pi^+)$ at 720 MeV/c by Hungerford and Tang.

the quasi free production must be taken into account before narrow Σ -state claims can be validated. In other cases, such as the $(K^-, \pi^+)^{12}\text{C}$ data from KEK, the evidence for Σ -states is stronger. Hungerford, however, has raised the question of whether final state interactions, like those producing the prominent cusp in the deuterium system, could be producing similar effects in ^{12}C . He also points out that the π^0 tagging would also enhance the final state interactions, inasmuch as they emphasize the Λ exit channel. Figure 5 shows he has been successful in reproducing at least two of the peaks in the (K^-, π^+) reaction on ^{12}C . I hope that further data from experiments in progress at KEK as reported by Chiba, and more refined calculations, will clarify these issues.

The lifetime and decay branching ratio measurements, appropriate to the weak decay of Λ hypernuclei, performed at the AGS were described in some detail by Gal in his plenary session talk. John Szymanski presented a status report on the extension of these measurements to the $A=5$ system from a study of $(K^-\pi^-)$ on ^6Li . Here we are studying the transition from the almost purely nucleonic weak decay mode in the mass 12 system to a case in which mesonic decay is presumably more evident. Figure 6 shows the prompt and delayed timing curves. Although a lifetime number is not yet available, the delayed time distribution is obviously

Fig. 6. The decay timing curve for ^5He ground state weak decay compared to the resolution function ($\sigma = 95$ ps).

distinct from the prompt timing curve. A remarkable resolution figure of 95 picoseconds (σ) has been obtained for the prompt distribution, indicating the excellent timing resolution achieved over a two-week running period. Calculation of the branching ratios is in progress.

Theoretical calculations for the nucleon-stimulated weak decay modes of Λ -hypernuclei were presented by Kisslinger and Dubach. Kisslinger uses a hybrid quark model which uses meson exchange for the long range part of the nuclear force, while treating the short range part with quark gluon exchange. Dubach uses a meson exchange treatment incorporating the $(SU_6)_w$ symmetry. Both emphasize the necessity of separating nuclear structure effects in order to understand the fundamental transition operator. A calculation of decay in the nuclear matter limit is inappropriate to a discussion of real nuclei. Both indicated the importance of experiments for $\Lambda = 4$ and $\Lambda = 5$ systems where the Λ -N α e in relative S-states for this separation.

A weak decay calculation for the Λ particle using the constituent quark model was presented by Golowich. He considered $\Delta S = 2$ and $\Delta S = 1$ transitions, appropriate to a more or less strongly bound Λ . The important result for cosmology is that the

Fig. 7. Calculations of the Λ -particle lifetime for $\Delta S = 2$ transitions (left) and $\Delta S = 1$ transitions (right).

estimated lifetime for the $\Delta S = 2$ transition is about 10^6 seconds. This rules out the H as a possible source of the Cygnus X-3 signal. For $\Delta S = 1$ transitions, a lifetime of 10^{-8} and 10^{-7} seconds is suggested, and these lifetimes have relevance to possible accelerator based searches for the H. The results are shown in Fig. 7.

A cloudy quark-bag model calculation of the kaon-nucleon interaction was presented by Byron Jennings, who pointed out that in his model the $\Lambda(1405)$ is predominantly an anti-kaon nucleon bound state, rather than a three-quark object. Joseph Speth presented results from his extension of the Bonn-potential to the Λ -nucleon system. Speth presents curves which illustrate the effects of the nuclear medium in altering the real two-body forces to effective two-body forces. In particular the large difference in the tensor forces between the NN and ΛN are reduced by polarization effects in nuclear matter (Fig. 8). These differences suggest that interpreting spin-orbit splittings in N and Σ hypernuclei, for example, in terms of a simple additive quark model, is not possible. C. Bennhold presented calculations for kaon photoproduction based on relativistic wave functions.

Fig. 8. Correlated (—) and uncorrelated (---) ΛN and NN 3S_1 wavefunctions in free space (left) and in nuclear matter (right).

Finally L. C. Liu presented a proposal to search for an eta-mesic bound nuclear system--a system which, if not strange, is certainly unusual. The ejection of a proton by a pion in ^{16}O and the simultaneous creation of an η at rest in the nucleus is kinematically possible at a pion incident momentum near 800 MeV/c. The idea is based on a suggestion made by J. C. Peng several years ago. The calculations of Liu indicate η binding starts near mass 12 and is possible for heavier systems (Fig. 9). An experimental search for η -bound nuclei will start at the AGS in January.

A wealth of nuclear physics problems involving strange quarks in nuclei exists. We need only the accelerator, facilities, and people to exploit this field.

Fig. 9. Diagram for η -hole states formed in $^{16}\text{O}(\pi^+, p)$.