The effect of these is the contraction of the muscle fibres.

\[ \frac{\partial^2 \sigma}{\partial t^2} = \frac{1}{\rho} \frac{\partial \sigma}{\partial t} + \frac{\sigma}{\rho} \]

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**The Formulation**

**Abstract**

**Conclusion**

**Introduction**

**Discussion**

**Conclusion**
terms are not unique to the CBM but are a consequence of the present realization of chiral symmetry. They would also appear in chiral potential models (either relativistic or nonrelativistic). Note that the time part of the vector current involves just the normalization integral of the quarks so all that can change from one chiral model to another is the form factor. It is the time part of the vector current that plays the most important role in my calculation so the qualitative conclusions are more general than the derivation through the CBM might suggest. I now expand the Lagrangian in powers of the meson fields and to lowest order the covariant derivatives become just the ordinary derivatives.

The details of how a calculation is done are given in considerable detail in Ref. 8. (They are also discussed to some extent in any of Refs. 1-11.) Only a brief sketch will be given here. The interaction terms are evaluated between bag model wave functions. The time part of the contact term (Eq. 5) gives a central potential which serves as a driving term in a Lippmann-Schwinger equation. The spatial part of the contact term contributes only a spin-orbit potential which I do not include since in this talk I will consider only s-wave scattering. Two terms involving one meson field must be combined with an energy denominator to give a bare resonance. This bare resonance is then also used as a driving term in the Lippman-Schwinger equation. Both the location and couplings of the resonances will be renormalized by the iteration in the Lippman-Schwinger equation. In the Lippman-Schwinger equation relativistic kinematics are used for the mesons, and the baryon is allowed to recoil.

THE RESULTS

As already mentioned I restrict my attention to s-waves. For pion-nucleon scattering the contact term evaluated in first Born approximation gives the correct scattering lengths, although considerably more work is required to get the energy dependence of the phase shifts correct. It is in fact necessary to include terms of higher order in the meson fields from the Lagrangian. These terms are expected to be somewhat less important for the kaon-nucleon system but there is evidence that they do contribute and work is now in progress to calculate them. It is not expected that they will change our results qualitatively.

In Fig. 1 (see Ref. 8) I show the results for s-wave kaon-nucleon scattering. A radius of 1.0 fm has been chosen for the bag. In the S11 channel the CBM does a good job of describing the data including the scattering length (see Ref. 10). In the S01 channel it gives a very small scattering length. Experimentally the sign of the scattering length is not well determined but its magnitude is small. It can be seen from the figure that we are missing repulsion which may arise from the higher order terms in the Lagrangian which I have so far neglected. Perhaps the main conclusion to be drawn from the S01 channel is the need for better data. From the kaon scattering we see that the CBM gives repulsion where repulsion is needed and small results where the experimental results are small although there is a clear signal of missing ingredients in the S01 channel where the present model gives very small results.

![Fig. 1. Phase shifts for (a) S01 and (b) S11 partial waves. My results are given by the solid curve for the S01 partial wave and by the dashed region (95 MeV < f < 105 MeV) for S11. The dots are Hashimoto's phase-shift analysis, while the dashed curves are the phase-shift analysis of Arndt and Roper for I=1 and Corden et al., for I=0. The dash-dot curves are the meson exchange model results of Davis et al.]

I now turn to the problem of real interest, the antikaon-nucleon in the S01 partial wave. The first point to be made is that in this channel the contact term is large and attractive. It is attractive for both the antikaon-nucleon and the pion-sigma. There is also a coupling between these two channels. I do not believe that it is an accident that the CBM gives attraction precisely where the quark models have the greatest difficulty fitting the data and give the state too high an energy. However, it is at this point that difficulties arise. There are two things one can visualize happening. One is that the attraction simply moves the lowest three quark state down in energy while leaving its structure more or less untouched. The second possibility is that the attraction creates a new state, an antikaon-nucleon bound state while leaving the three quark state or states relatively untouched. From numerical studies it appears quite difficult to realize the first scenario. The problem arises when one tries to lower a resonance past a threshold. As the attraction is increased the state does move down in energy but at some point a new state will appear. This is what happens in the CBM. The situation is a bit more complicated in real life because there is not just a single three quark state but three of them and, moreover, if there is a bound state one of the three quark states is not seen experimentally.

To check our model I compare against two types of data, first there is the pion-sigma mass spectrum measured by Hemingway for $k^+p + \pi^+ = \Sigma^+ + \pi^+ + \pi^+$. This gives us information on the pion-sigma cross...
bound state. The second point is that I have chosen to fit the phase shift analysis of Gopal et al. 23. Within the CBM it is much more difficult to fit the analysis of Martin et al. 24 and by trial and error I was unable to get a good fit, although this does not prove it is impossible. On the other hand the nonrelativistic quark model is much more consistent with the analysis of Martin. For example, Martin's analysis gives a large coupling of the A(1800) to the sigma-pi channel, while in the analysis of Ref. 23 it almost decouples from that channel. The nonrelativistic quark model predicts a large coupling 25, 26 and is thus inconsistent with Ref. 23. To oversimplify things, Martin's analysis is consistent with the following scenario: the three nonrelativistic quark model states are all that are present but one of them is shifted down in energy, possibly by the attraction we have seen. The analysis of Gopal et al. 23 on the other hand has couplings that are inconsistent with that scenario but is consistent with the A(1405) being a bound state and the higher resonances being almost pure SU(3) states. Thus we see that data in this higher energy region would put severe constraints on models of the A(1405).

CONCLUSION

In conclusion we have seen that the CBM is quite capable of describing the kaon and antikaon scattering. The CBM also suggests very strongly that the A(1405) is an antikaon-nucleon bound state and I have shown that this is consistent with the scattering data up to the region of the A(1800), provided the analysis of Ref. 23 is correct. It is very important that the ambiguities in the phase shift analysis in the SU(3) partial wave be resolved.

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