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LETTER TO THE EDITOR

THE ROLE OF THE PION CLOUD IN THE NUCLEON FORM FACTORS

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In the linear sigma model and in the chromodielectric model, it is shown how the pion cloud enhances the electric polarizability, the electroexcitation of the Δ and the axial form factor, and how it reduces the magnetic polarizability.

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Many properties of the nucleon can be rather successfully explained by assuming a cloud of pions surrounding the quark core.

Here we are interested in those quantities which are particularly sensitive to the pionic content of the nucleon and can not be explained in a model with only quark degrees of freedom (without making additional ad hoc assumptions). Examples are the electric and magnetic polarizabilities and different form factors as measured in pion electroproduction experiments.

We calculate these properties in the linear sigma model (LSM) [1,2] as a generic example of models predicting a rather strong pion cloud in (nonstrange) baryons as well as in the chiral version of the chromodielectric model (CDM) [2] which has a weaker pion cloud. Coherent states are used to describe the meson clouds around the quark core and we perform an exact projection of isospin and angular momentum [3].

The *electric polarizability* [4] is too large by the factor two in the LSM ($23 \cdot 10^{-4}$ fm^3), due to the very large contribution of the term quadratic in $\mathcal{E}$

in which the photon interacts directly with the pion (this term corresponds to the seagull diagram in the chiral perturbation theory). This term is particularly sensitive to the pionic tail (the integral is weighted with r^4), and variational calculations with respect to energy are simply inadequate to adjust this fine detail. The situation is opposite for the *magnetic polarizability*: here relatively strong ("diamagnetic") pion cloud is needed in order to compensate the large paramagnetic term due to the virtual Δ excitation. A weaker pion cloud, that would improve the electric polarizability, would spoil the magnetic one. This apparent contradiction may be partially attributed to too crude approximations used in the calculation; nevertheless, since the pure quark model predicts much too small values for the polarizabilities, the calculation demonstrates the major role played by the pion cloud in determining the polarizabilities.

The amplitudes for *electroproduction* of low lying baryon resonances can also yield sensible information on the pion content of the nucleon and its excited states [5]. In particular, relatively large quadrupole $E2$ (or E_{1+}) and $C2$ (S_{1+}) amplitudes in the vicinity of the $\Delta(1232)$ resonance can be almost entirely attributed to the cloud of p-wave pions. In quark models without the pion cloud, an unrealistically strong admixture of d-state quarks would have to be introduced in order to explain the experimental values. In the LSM, which has a relatively strong pion field as opposed to the CDM, the $S_{1/2}$ helicity amplitude for the electroproduction of the Δ resonance (proportional to S_{1+} electroproduction amplitude) clearly indicates a sizeable pion content of the nucleon (Fig. 1). Correspondingly, the calculated $A_{1/2}$ and $A_{3/2}$ helicity amplitudes reproduce the experimental values better in the LSM than in the CDM, mostly due to a large contribution of pions which is around 50% for the LSM and much smaller in the CDM.

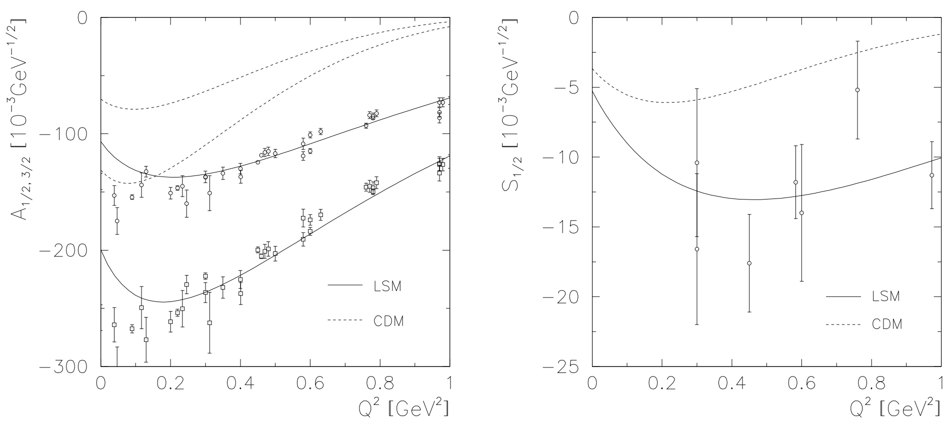

Fig. 1. Helicity amplitudes $A_{1/2}$, $A_{3/2}$ and $S_{1/2}$ for electroexcitation of the Δ in the LSM (solid lines) and CDM (dotted lines). In the left figure, the upper two curves and the full circles (experiment) correspond to $A_{1/2}$, the lower two curves and the hollow circles to $A_{3/2}$.

Pions also exhibit a large contribution to the *axial form factor* of the nucleon [6]. The normalized axial form factor (Fig. 2) shows a good agreement with the experimental one in the LSM, but falls off too rapidly in the CDM. In the LSM, the pion contribution is sizeable (between 30% to 40%). Performing the linear momentum projection improves the agreement with the experiment. On the other hand, the absolute value of the form factor (also $g_{\rm A}(0)$) is too large compared to the experimental value of 1.267 (1.8 in the LSM or 1.6 in the CDM). The interpretation in terms of the pion cloud is less clear here since in both models, the axial charge appears as a cross term between the pion and sigma fields.

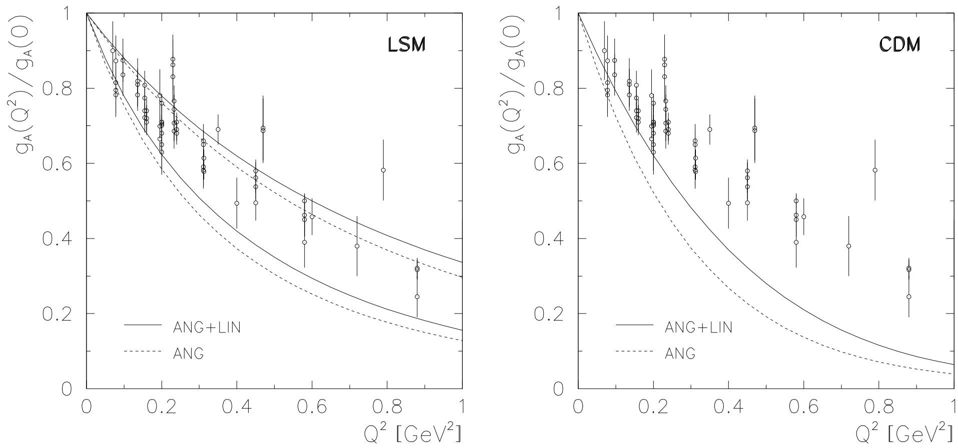

Fig. 2. The normalized axial form factor $g_{\rm A}(q^2)/g_{\rm A}(0)$ in the LSM (for two sets of parameters) and CDM, in comparison to experimental data. The dashed curves correspond to angular momentum projection only and the full curves to additional linear momentum projection.

Since the chiral fields are determined variationally, we may suspect that they would be overestimated, especially in the LSM where they are the only fields responsible for binding the quarks. We may still conclude that the pion cloud also plays a major role here.

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ULOGA PIONSKOG OBLAKA U NUKLEONSKIM FAKTORIMA OBLIKA

U linearnom sigma modelu i u kromodielektričnom modelu se pokazuje kako pionski oblak povećava električnu polarizivnost, elektrouzbudu Δ i aksijalni faktor oblika, te kako smanjuje magnetsku polarizivnost.