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Extended vector meson dominance model for the baryon octet electromagnetic form factors

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An unresolved issue in the present understanding of nucleon structure is the effect of hidden strangeness on electromagnetic observables such as $G_E^n(q^2)$. Previously, we have shown that $G_E^n(q^2)$ is sensitive to small ϕNN couplings. A complementary approach for understanding effects due to strangeness content and the Okubo-Zweig-Iizuka (OZI) rule is to investigate the electromagnetic structure of hyperons. We apply Sakurai's universality limit of the $SU(3)_F$ symmetry relations and a prescription based on the OZI rule to calculate the electromagnetic form factors of the baryon octet states $(p,n,\Lambda,\Sigma^+,\Sigma^0,\Sigma^-,\Xi^0,\Xi^-)$ within the framework of an extended vector meson dominance model. To provide additional motivation for experimental investigation, we discuss the possibility of extracting the ratio $G_M^{\Lambda}(q^2)/G_M^{\Sigma\Lambda}(q^2)$ from the Λ/Σ polarization ratio in kaon electroproduction experiments.

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I. INTRODUCTION

Hadronic structure is a topic of fundamental importance in nuclear physics. The distribution of quarks and gluons bound by nonperturbative interactions inside the hadron gives rise to a complicated many-body structure which, except for very short distances where perturbative QCD (PQCD) applies, is up to the present time unsolvable from first principles. In order to make progress in understanding the nonperturbative features of hadron structure, one has to resort to calculations based on phenomenological models. In this paper, we calculate the electromagnetic form factors of the ground state baryon octet in an extended vector meson dominance formalism. Up to the present time there are no form factor measurements of the strange baryons; however, with the advent of new experimental facilities such as CEBAF it is feasible that some of the hyperon form factors may be measurable. In the final section, we suggest a possibility for extracting $G_M^{\Lambda}(q^2)$ from the Λ polarization in kaon electroproduction, $p(e,e'K^+)\vec{\Lambda}$, experiments.

Our original analysis [1] was motivated by new timelike proton magnetic form factor data which have been determined recently from measurements of the exclusive cross section for electron-positron production (annihilation) by proton-antiproton annihilation (production), $p\bar{p}\leftrightarrow e^+e^-$. The new precision data have been obtained for momentum transfers in the region $8.9\leqslant q^2\leqslant 13$ GeV^2 (Fermilab E-760) [2] and in the vicinity of the proton-antiproton threshold (LEAR PS170) [3]. There are also new, but less precise, timelike data (including one G_E^n point) from the FENICE experiment [4]. Perturbative QCD calculations are usually compared with data for spacelike momentum transfers larger than $Q^2\sim 10$ GeV^2 [5,6]. The new Fermilab E-760 data confirm the predictions of perturbative QCD for the slope of the magnetic form factor in the timelike region [2]. Several versions of the vector meson dominance (VMD) model [7–12], on the other hand, predict a slope of the magnetic form factor of the proton at the proton-antiproton threshold which is about five times smaller than the the new Low Energy Antiproton Ring (LEAR) data. Given the apparent failure of the vector meson dominance model and the success of PQCD, the data have been used to derive a running coupling constant in the timelike region [2].

Our approach is to employ effective vector meson–nucleon interactions to study the electromagnetic structure of the octet baryons. We employ a hybrid vector meson dominance (HVMD) formalism, which is a generalization of the model developed by Gari and Krümpelmann [13]. The model provides a smooth transition from the low-q^2 behavior predicted by vector meson dominance to the high-q^2 scaling behavior predicted by PQCD. The essential contribution of this work is to appy Sakurai's universality limit of the vector meson hadronic coupling $SU(3)_F$ symmetry relations and a prescription based on the OZI rule to extend our previous model to the baryon octet.

As in our previous work, we include two speculative vector meson resonances (one below and one above the $N\bar{N}$ threshold) which account for the local structure seen in the LEAR PS170 data. We assign the isospin such that the lighter excited state is an isoscalar (ω'') and the heavier excited state is isovector (ρ''). The masses and decay widths of these states have been determined in our previous paper [1]. All other vector meson states, the $\rho(770)$, $\omega(784)$, $\phi(1020)$, $\omega'(1600)$, and $\rho'(1700)$, are given their physical masses and widths. Each vector meson has two effective couplings (vector and tensor) to each octet baryon. These couplings are determined by applying $SU(3)_F$ relations in the universality limit [14,15]. A fundamental feature of vector meson universality is that the isovector ρ meson couples with strength proportional to isotopic charge, the isoscalar octet ω_8 meson couples proportionally to hypercharge (Y), and the unitary singlet isoscalar ω_1 couples universally to baryon number (β). Since the physical ω and ϕ states are believed to be "ideally mixed" states of ω_1 and ω_8 [16] [i.e.,

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TABLE I. Vector and tensor coupling coefficients of the hybrid vector meson dominance model. The direct $F^{\gamma}_{1,2}$ form factors have scale parameter $\lambda=2.0$ GeV. The starred values were fixed by low-energy πN scattering analyses. The universality-violating parameter $\delta=0.1$, which reproduces the effective ϕNN coupling of our previous work.

V	$C_V(N)$	$C_V(\Sigma)$	$C_V(\Lambda)$	$C_V(\Xi)$	κ_V	C_V
ρ	0.4	0.53	0	0.13	6.10*	0.4
ρ'	−2.0	−2.66	0	−0.66	0.1	−2.0
ρ''	1.6	2.13	0	0.53	0.2	1.6
γ^{IV}	1.0	2.0	0	1.0		1.0
ω	0.2	0.167	0.167	0.133	0.14*	0.1
ω'	1.2	0.8	0.8	0.4	−0.3	1.2
ω''	−0.3	−0.2	−0.2	−0.1	−0.1	−0.3
ϕ	−0.1	−1.1	−1.1	−2.1	−1.82	1.0
γ^{IS}	0	0.333	0.333	0.667		1.0

the ω is an isospin zero combination of only $(u\bar{u}+d\bar{d})$ quarks and the ϕ is an isosinglet combination of only $s\bar{s}$ quarks], their effective couplings should be a linear combination of the universal ω_1 and ω_8 couplings. Furthermore, because of the famous Gell-Mann relation

$$Q=I_3+\frac{1}{2}(\beta+S), \tag{1}$$

which relates the octet baryon and meson charges (Q) to isospin (I_3), baryon number (β), and strangeness (S), with $Y=\beta+S$, it is natural to apply the universality hypothesis of Sakuari in the following way. We associate each of the three types of vector meson states (ρ, ω, and ϕ) with a corresponding conserved "charge" (isospin, baryon number, and strangeness, respectively). Specifically, the universality relations that we employ in this work are

$$C_\rho(b)=2I_3^b\left(\frac{Y_b+2}{3}\right)C_\rho, \tag{2}$$

$$C_\omega(b)=\beta_b\left(\frac{Y_b+2}{3}\right)C_\omega+\delta, \tag{3}$$

$$C_\phi(b)=S_bC_\phi-\delta, \tag{4}$$

$$C_{\rho',\rho''}(b)=2I_3^b\left(\frac{Y_b+2}{3}\right)C_{\rho',\rho''}, \tag{5}$$

$$C_{\omega',\omega''}(b)=\beta_b\left(\frac{Y_b+2}{3}\right)C_{\omega',\omega''}, \tag{6}$$

$$C_\gamma^{\mathrm{IV}}(b)=2I_3^bC_\gamma^{\mathrm{IV}}, \tag{7}$$

$$C_\gamma^{\mathrm{IS}}(b)=\beta_b\left(\frac{1-Y_b}{3}\right). \tag{8}$$

The coefficient $((Y_b+2)/3)$, which is the ratio of nonstrange quarks to the total number of quarks in the octet baryon (i.e. 1 for N, 2/3 for Λ or Σ, and 1/3 for Ξ), is our implementation of the OZI rule, which suppresses the ρ and ω couplings to the strange baryons. Note that the ϕ coupling is OZI suppressed to the nucleon states and enhanced to the strange baryons, which our model incorporates since the ϕ couples to strangeness. The constant δ allows for an antisymmetric violation of universality between the ω and ϕ states, since there is a possibility that the nucleon has a nonzero $s\bar{s}$ sea quark distribution which allows for an OZI-evading ϕNN coupling; conversely, in the meson sector where $\beta=0$, the ω can have a nonzero coupling to the pion or kaon. To satisfy the Gell-Mann relation, the isovector and isoscalar couplings of each octet baryon must satisfy the following sum rules:

$$\sum_V^{\mathrm{IV}} C_V(b)=2I_3^b, \tag{9}$$

$$\sum_V^{\mathrm{IS}} C_V(b)=\beta_b+S_b. \tag{10}$$

These conditions imply corresponding sum rules for the universal couplings of each type of vector meson:

$$\sum_\rho C_\rho=0, \quad C_\gamma^{\mathrm{IV}}=1, \tag{11}$$

$$\sum_\omega C_\omega=1, \quad \sum_\phi C_\phi=1. \tag{12}$$

These relations, which follow directly from the universality hypothesis, are precisely satisfied by the couplings of our nucleon form factor model, where we did a global fit to all the spacelike and timelike data [1] without constraints. We assume the effective tensor couplings $\kappa_V(b)C_V(b)$ obey the same universality relations and hence the ratios of tensor to vector couplings are independent of the baryon [i.e., $\kappa_V(b)\equiv\kappa_V$]. We list the universal vector and tensor couplings of our model in Table I. The parameters corresponding to the form factors of each of the octet charge states are found by applying Eqs. (2)–(8) with the universal couplings listed in Table I. In the next section we discuss the model formalism and establish some notation.

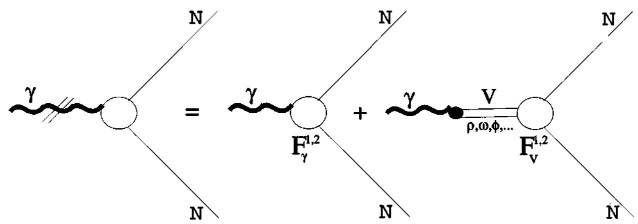

FIG. 1. Hybrid vector meson dominance picture of a physical photon coupling to a baryon.

II. HYBRID VECTOR MESON DOMINANCE

The basic assumption of HVMD is that the physical photon couples to the nucleon either in a hard perturbative mode (the direct term) or mediated by vector meson intermediate states (see Fig. 1). The electromagnetic baryon form factors are defined by the usual current matrix element:

$$\langle B;p'|J_\mu^i|B;p\rangle \equiv u_B(p')\left[F_1^i(B;q^2)\gamma_\mu + \frac{i\sigma_{\mu\nu}(p'-p)^\nu}{2M}\kappa_i^B F_2^i(B;q^2)\right]\mathscr{T}_i^{(B)}u_B(p), \tag{13}$$

where the index $i=\mathrm{IS,IV}$ labels the isospin (0 or 1) and $B=N,\Sigma,\Lambda,\Xi$. The corresponding isospin operators are $\mathscr{T}_{\mathrm{IS}}(B)=1$ (for all baryons), the unit matrix in the space of isospin, and

$$\mathscr{T}_{\mathrm{IV}}^{(\Lambda)}=0, \quad \mathscr{T}_{\mathrm{IV}}^{(N,\Xi)}=\frac{1}{2}\tau_3=\frac{1}{2}\begin{pmatrix}1 & 0\\ 0 & -1\end{pmatrix},$$

$$\mathscr{T}_{\mathrm{IV}}^{(\Sigma)}=\begin{pmatrix}1 & 0 & 0\\ 0 & 0 & 0\\ 0 & 0 & -1\end{pmatrix} \tag{14}$$

for isovector particles. $q^2=(p'-p)^2$ is the invariant momentum transfer of the photon. The Sachs electric and magnetic baryon form factors of the individual charge states are the standard linear combinations:

$$G_M^b(q^2)\equiv F_1^b(q^2)+F_2^b(q^2), \tag{15}$$

$$G_E^b(q^2)\equiv F_1^b(q^2)+\frac{q^2}{4M^2}F_2^b(q^2), \tag{16}$$

where $b=p,n,\Sigma^+,\Sigma^o,\Sigma^-,\Lambda,\Xi^o,\Xi^-$. The net F_1^b and F_2^b form factors of each charge state are linear combinations of the isospin functions:

$$F_1^b(q^2)\equiv\frac{1}{2}N_b[F_1^{\mathrm{IS}}(B;q^2)+r_bF_1^{\mathrm{IV}}(B;q^2)], \tag{17}$$

$$F_2^b(q^2)\equiv\frac{1}{2}N_b[\kappa_{\mathrm{IS}}^B F_2^{\mathrm{IS}}(B;q^2)+r_b\kappa_{\mathrm{IV}}^B F_2^{\mathrm{IV}}(B;q^2)], \tag{18}$$

where

$$N_b\equiv 1+\delta(I_3^b,0), \tag{19}$$

$$r_b\equiv\frac{I_3^b}{|I_3^b|+\delta(I_3^b,0)}, \tag{20}$$

$$I_3^b\equiv\langle b|\hat{I}_3|b\rangle. \tag{21}$$

I_b^3 is the third component isospin eigenvalue of state b. Evaluating the diagrams of Fig. 1 we obtain the HVMD isospin form factors of the octet baryons:

$$F_1^{\mathrm{IV}}(B;q^2)=\left[\sum_V^{\mathrm{IV}} C_V(B)\left(\frac{M_V^2}{M_V^2-q^2+iM_V\Gamma_V}\right)F_1^V(q^2)\right] + C_\gamma^{\mathrm{IV}}(B)F_1^\gamma(q^2), \tag{22}$$

$$F_1^{\mathrm{IS}}(B;q^2)=\left[\sum_V^{\mathrm{IS}} C_V(B)\left(\frac{M_V^2}{M_V^2-q^2+iM_V\Gamma_V}\right)F_1^V(q^2)\right] + C_\gamma^{\mathrm{IS}}(B)F_1^\gamma(q^2), \tag{23}$$

$$\kappa_{\mathrm{IV}}^B F_2^{\mathrm{IV}}(B;q^2)=\left[\sum_V^{\mathrm{IV}} \kappa_V(B)C_V(B)\times\left(\frac{M_V^2}{M_V^2-q^2+iM_V\Gamma_V}\right)F_2^V(q^2)\right] + \kappa_\gamma^{\mathrm{IV}}(B)C_\gamma^{\mathrm{IV}}(B)F_2^\gamma(q^2), \tag{24}$$

$$\kappa_{\mathrm{IS}}^B F_2^{\mathrm{IS}}(B;q^2)=\left[\sum_V^{\mathrm{IV}} \kappa_V(B)C_V(B)\times\left(\frac{M_V^2}{M_V^2-q^2+iM_V\Gamma_V}\right)F_2^V(q^2)\right] + \kappa_\gamma^{\mathrm{IS}}(B)C_\gamma^{\mathrm{IS}}(B)F_2^\gamma(q^2), \tag{25}$$

where $C_V(B)\equiv(g_{VBB}/f_V)$ is the effective coupling to baryon B, with f_V the vector meson leptonic decay constant and g_{VBB} the hadronic coupling constant. The effective vector and tensor couplings of the direct photon isoscalar and isovector terms are determined by the charge and magnetic moment normalizations (consistent with the universality conditions):

$$C_\gamma^{\mathrm{IV}}(B)=\mathscr{N}_1^{\mathrm{IV}}(B)-\sum_V^{\mathrm{IV}} C_V(B), \tag{26}$$

$$C_\gamma^{\mathrm{IS}}(B)=\mathscr{N}_1^{\mathrm{IS}}(B)-\sum_V^{\mathrm{IV}} C_V(B), \tag{27}$$

$$\kappa_\gamma^{\mathrm{IV}}(B)C_\gamma^{\mathrm{IV}}(B)=\kappa_{\mathrm{IV}}^B\mathscr{N}_2^{\mathrm{IV}}(B)-\sum_V^{\mathrm{IV}}\kappa_V(B)C_V(B), \tag{28}$$

$$\kappa_\gamma^{\mathrm{IS}}(B)C_\gamma^{\mathrm{IS}}(B)=\kappa_{\mathrm{IS}}^B\mathscr{N}_2^{\mathrm{IS}}(B)-\sum_V^{\mathrm{IS}}\kappa_V(B)C_V(B), \tag{29}$$

where

$$\mathscr{N}_1^{\mathrm{IV}}(B)\equiv F_1^{\mathrm{IV}}(B;q^2=0), \tag{30}$$

$$\mathscr{N}_1^{\mathrm{IS}}(B)\equiv F_1^{\mathrm{IS}}(B;q^2=0), \tag{31}$$

$$\mathscr{N}_2^{\mathrm{IV}}(B)\equiv F_2^{\mathrm{IV}}(B;q^2=0), \tag{32}$$

TABLE II. Normalizations for the isospin functions.

	N	Σ	Λ	Ξ
$\mathcal{N}_1^{\mathrm{IS}}(B)$	1	0	0	-1
$\mathcal{N}_1^{\mathrm{IV}}(B)$	1	2	0	1
$\mathcal{N}_2^{\mathrm{IS}}(B)$	1	2	1	1
$\mathcal{N}_2^{\mathrm{IV}}(B)$	1	2	0	1

$$\mathcal{N}_2^{\mathrm{IS}}(B) \equiv F_2^{\mathrm{IS}}(B;q^2=0). \tag{33}$$

These isospin function normalizations are listed in Table II.

Total isospin conservation requires that

$$F_1^{\mathrm{IV}}(\Lambda;q^2)=F_2^{\mathrm{IV}}(\Lambda;q^2)=0. \tag{34}$$

The isosopin function normalizations ensure the correct charge and magnetic moment values are obtained for each octet state (listed in Table III). Experimental values are taken for the octet baryon magnetic moments which are used to determine the net isoscalar and isovector tensor coupling ($\kappa^B_{\mathrm{IS,IV}}$) to each baryon state ($B$).

The direct coupling form factors ($F^{\gamma}_{1,2}$) are chosen such that the low-q^2 behavior is given by a ρ-dominance monopole with a transition to the correct PQCD scaling behavior at high q^2 [13]. The vector meson to quark transition scale is set by the parameter λ:

$$F_n^{\gamma}(q^2)=\left[\frac{M_\rho^2(M_\rho^2+\Gamma_\rho^2)}{(q^2-M_\rho^2)^2+(M_\rho\Gamma_\rho)^2}\right]^{1/2}\left(\frac{\lambda^2}{\lambda^2+|q^2|}\right)^n \quad (n=1,2). \tag{35}$$

The specification of the vector meson nucleon vertex function is a model dependent assumption. Following Gari and Krümpelmann we take

$$F_n^V(q^2)=F_n^{\gamma}(q^2) \quad (n=1,2) \quad (\forall_V). \tag{36}$$

TABLE III. Electric and magnetic moment normalizations. Experimental magnetic moments are in Bohr magneton units ($e\hbar/2M_pc$).

b	G_E^b	G_M^b	G_M^b (expt.)
p	1	$1+\frac{1}{2}(\kappa^N_{\mathrm{IS}}+\kappa^N_{\mathrm{IV}})$	2.793
n	0	$\frac{1}{2}(\kappa^N_{\mathrm{IS}}-\kappa^N_{\mathrm{IV}})$	-1.913
Σ^+	1	$1+(\kappa^\Sigma_{\mathrm{IS}}+\kappa^\Sigma_{\mathrm{IV}})$	2.33
Σ^0	0	$\kappa^\Sigma_{\mathrm{IS}}$	
Σ^-	-1	$-1+(\kappa^\Sigma_{\mathrm{IS}}-\kappa^\Sigma_{\mathrm{IV}})$	-1.41
Λ	0	$\kappa^\Lambda_{\mathrm{IS}}$	-0.61
Ξ^0	0	$\frac{1}{2}(\kappa^\Xi_{\mathrm{IV}}+\kappa^\Xi_{\mathrm{IS}})$	-1.253
Ξ^-	-1	$-1+\frac{1}{2}(\kappa^\Xi_{\mathrm{IS}}-\kappa^\Xi_{\mathrm{IV}})$	-0.65

TABLE IV. Nucleon charge radius contributions from each vector meson resonance in units of fm^2. The net charge radii of the proton and neutron, given by Eq. (38), are $\langle R_p^2\rangle=0.675$ fm^2 and $\langle R_n^2\rangle=-0.091$ fm^2.

V	$R_N^2(V)$	$R_\Sigma^2(V)$	$R_\Lambda^2(V)$	$R_\Xi^2(V)$
ρ	0.248	0.328	0.0	0.081
ρ'	-0.534	-0.710	0.0	-0.176
ρ''	0.408	0.543	0.0	0.135
γ_{IV}	0.261	0.139	0.0	0.247
$\Sigma_{\mathrm{IV}}R_B^2(V)$	0.383	0.422	0.0	0.287
ω	0.084	0.070	0.070	0.055
ω'	0.311	0.207	0.207	0.104
ω''	-0.076	-0.051	-0.051	-0.025
ϕ	-0.027	-0.303	-0.303	-0.578
γ_{IS}	0.0	0.030	-0.006	-0.006
$\Sigma_{\mathrm{IS}}R_B^2(V)$	0.292	-0.047	-0.083	-0.450

III. NUMERICAL RESULTS

In Table IV, we compute the contribution of each vector particle to the the net charge radius of the nucleon from the relation

$$\langle R_b^2\rangle \equiv 6\frac{\partial G_E^b(q^2)}{\partial q^2}\bigg|_{q^2=0} \tag{37}$$

$$=\frac{1}{2}N_b\left[\sum_V^{\mathrm{IS}}+r_b\sum_V^{\mathrm{IV}}\right]R_B^2(V). \tag{38}$$

Taking the derivative of $G_E^b(q^2)$, we find the expression

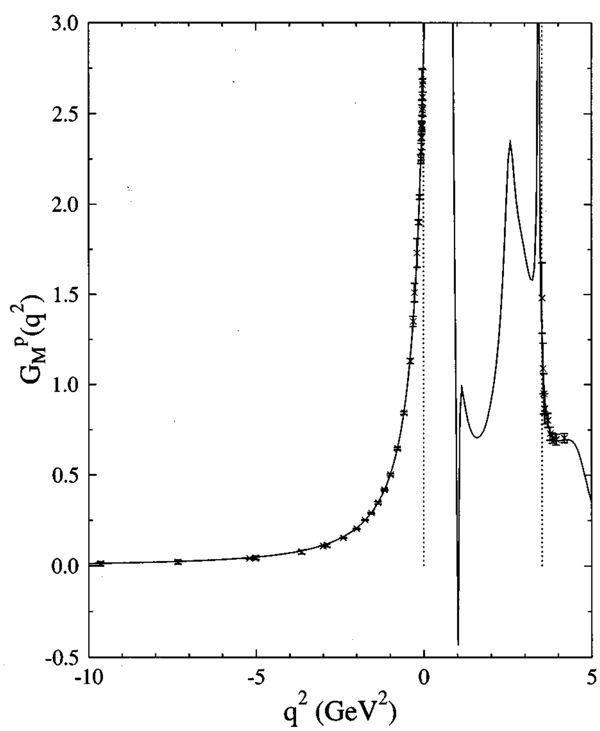

FIG. 2. Proton magnetic form factor G_M^p. The data are from Refs. [2,3,17].

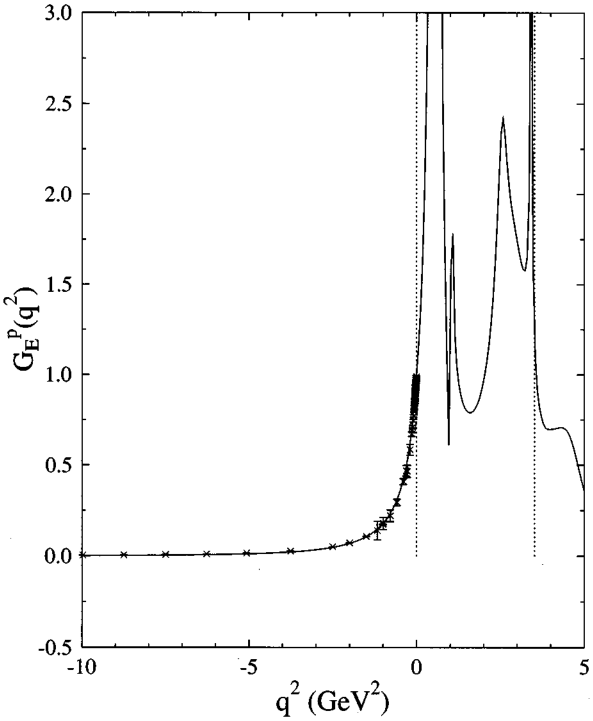

FIG. 3. Proton electric form factor G_E^p. The data are from Ref. [17].

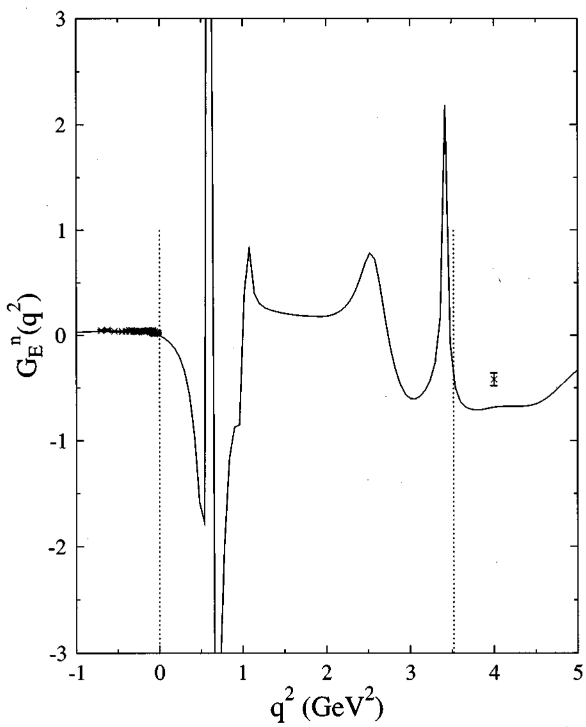

FIG. 5. Neutron electric form factor G_E^n. The data are from Refs. [4,19–21].

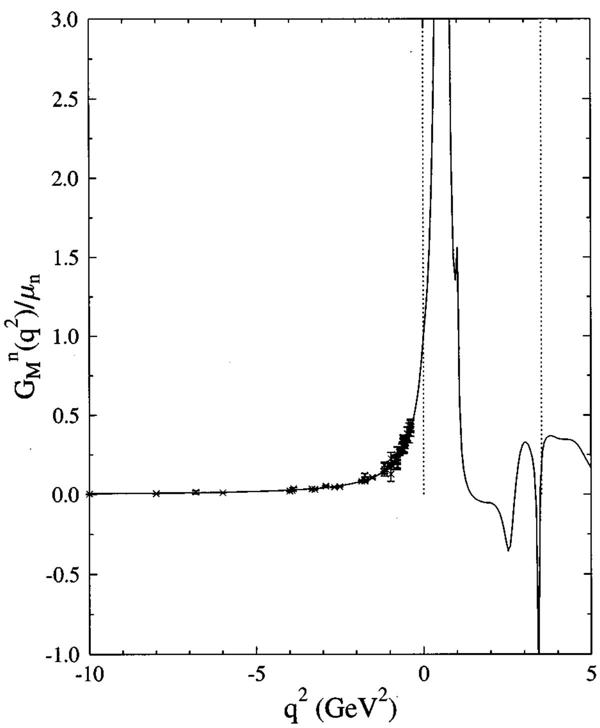

FIG. 4. Neutron magnetic form factor G_M^n/μ_n. The data are from Ref. [18].

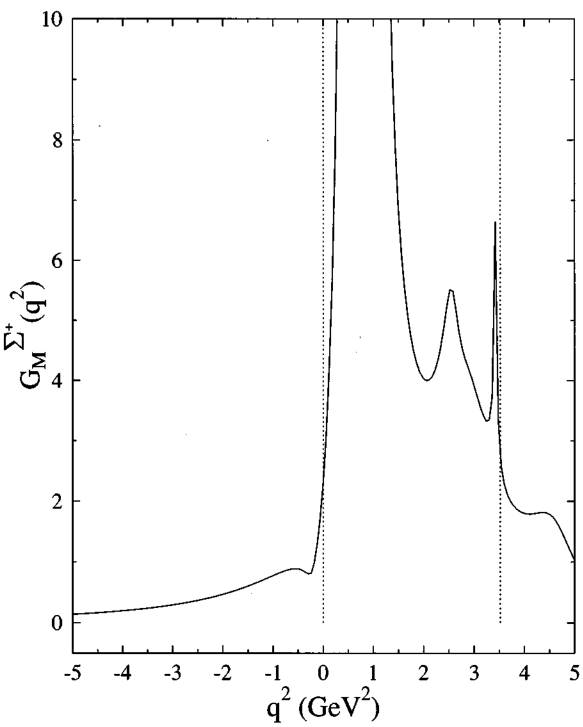

FIG. 6. Σ^+ magnetic form factor $G_M^{\Sigma^+}$.

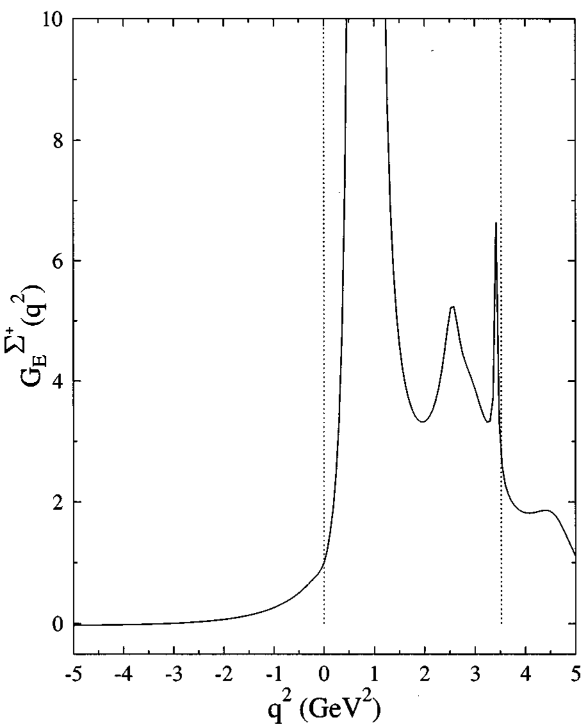

FIG. 7. Σ^+ electric form factor $G_E^{\Sigma^+}$.

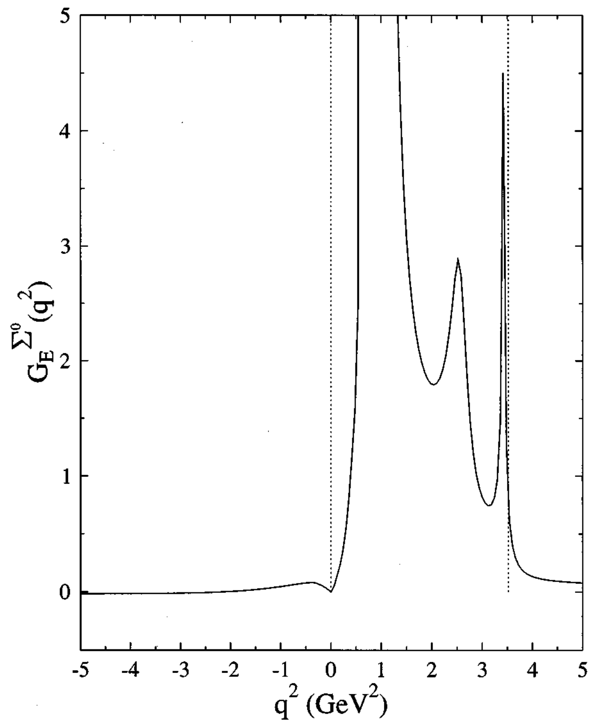

FIG. 9. Σ^0 electric form factor $G_E^{\Sigma^0}$.

$$R_B^2(V)=6C_V(B)\left[\frac{1-\delta(V,\gamma)}{M_V^2}+\frac{\kappa_V}{4M_N^2}+\left(\frac{1}{M_\rho^2}+\frac{1}{\lambda^2}\right)\right], \tag{39}$$

which we use to evaluate the elements of Table IV. Note the strong cancellation between the ρ' and ρ'' isovector states in the charge radii. Also, it is interesting that since we find $C_\omega(B)\ll C_{\omega'}(B)$, the $\omega'(1600)$ resonance contributes more strongly to the net isoscalar radii for each baryon than the (substantially lighter) ground state ω.

In Figs. 2–5 we display our model results for $G_{M,E}^{p,n}(q^2)$ in both the spacelike and timelike regions. To show the quali-

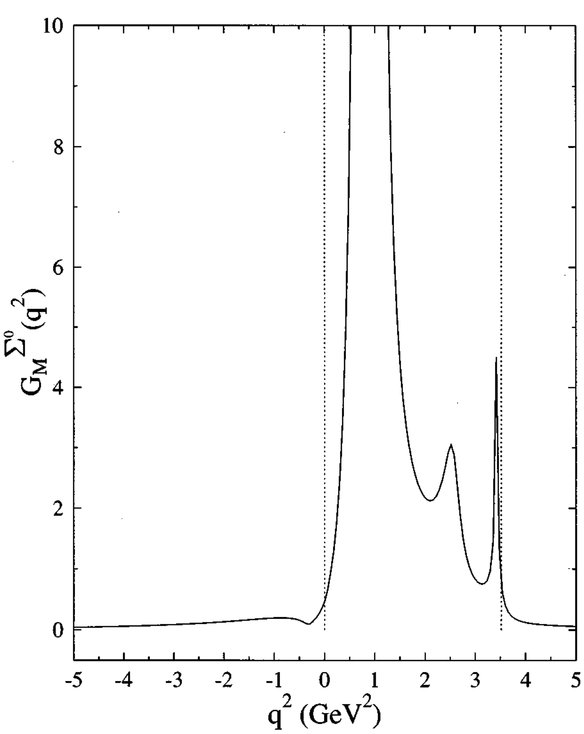

FIG. 8. Σ^0 magnetic form factor $G_M^{\Sigma^0}$.

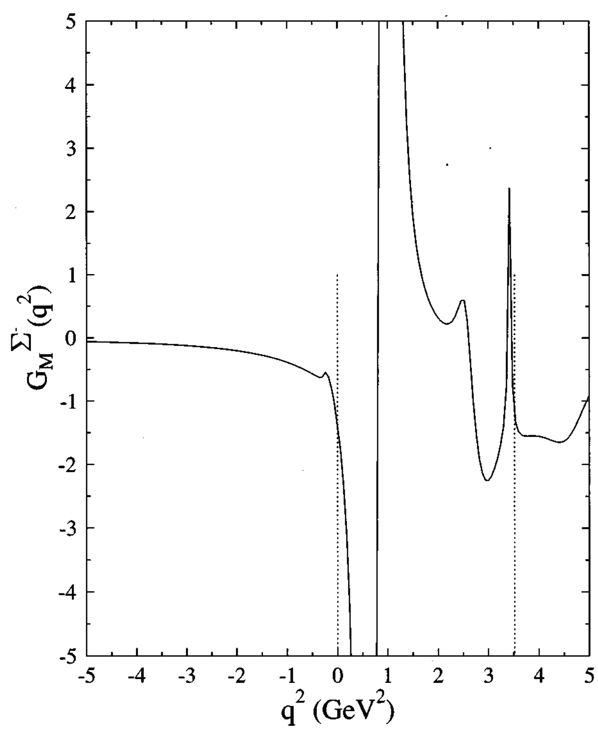

FIG. 10. Σ^- magnetic form factor $G_M^{\Sigma^-}$.

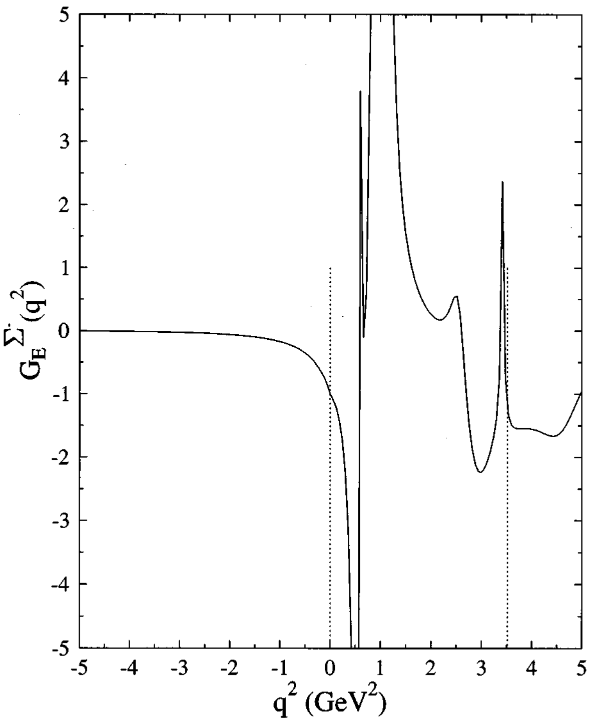

FIG. 11. Σ^- electric form factor $G_E^{\Sigma^-}$.

tative contributions from the various resonances, we also display the behavior of the timelike form factors in the unphysical region (i.e., below the appropriate $B\bar{B}$ threshold). It is evident that the HVMD parametrization gives a very good account of the available nucleon data. We are unable to obtain agreement with the timelike data if the excited vector

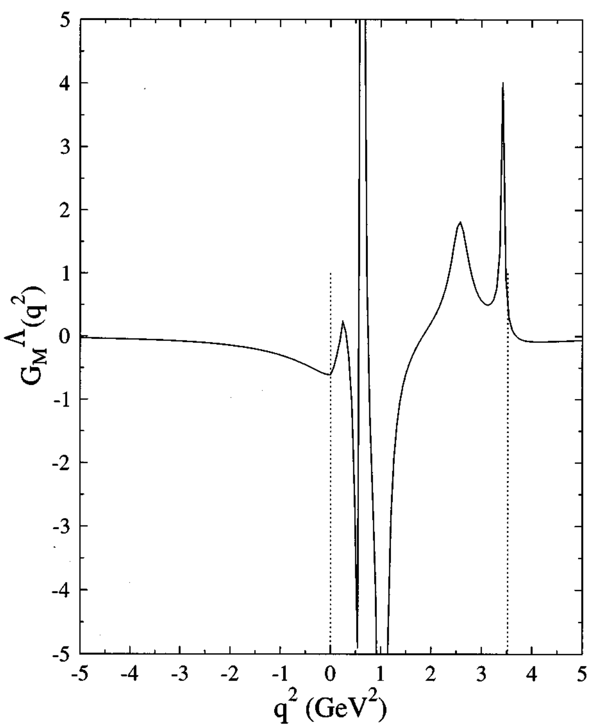

FIG. 12. Λ magnetic form factor G_M^{Λ}.

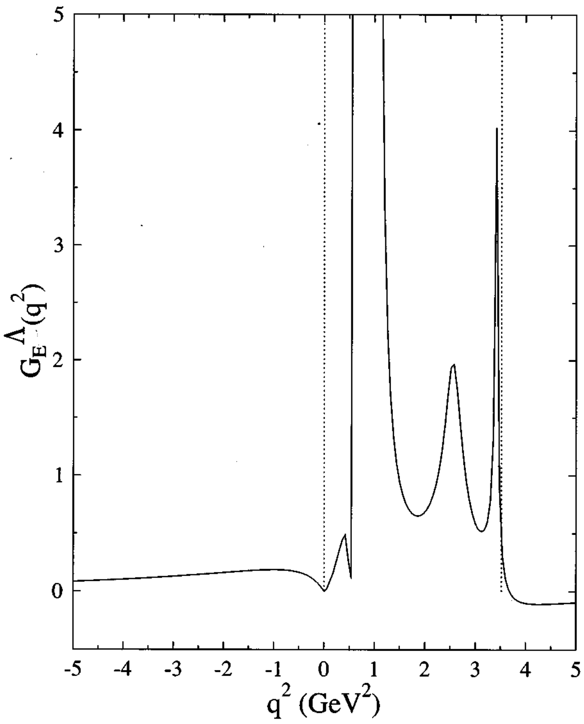

FIG. 13. Λ electric form factor G_E^{Λ}.

resonances are neglected. In Figs. 6–17 we show our model predictions for all of the other octet baryon form factors. We note that all of the magnetic $\Sigma^{+,0,-}$ form factors have an interesting dip feature in the spacelike region. Note also that the dip occurs at $q^2 \ll \lambda^2$ and hence should not be interpreted as interference between the vector meson and direct coupling

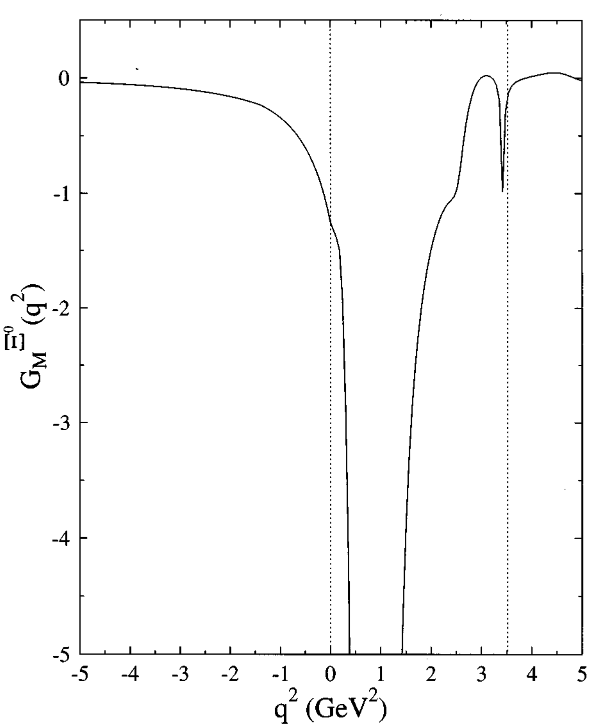

FIG. 14. Ξ^0 magnetic form factor, $G_M^{\Xi^0}$.

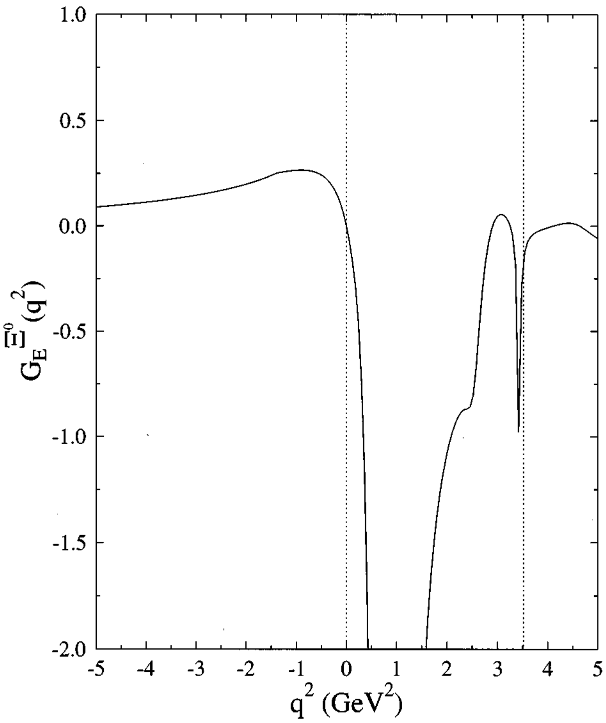

FIG. 15. Ξ^0 electric form factor, $G_E^{\Xi^0}$.

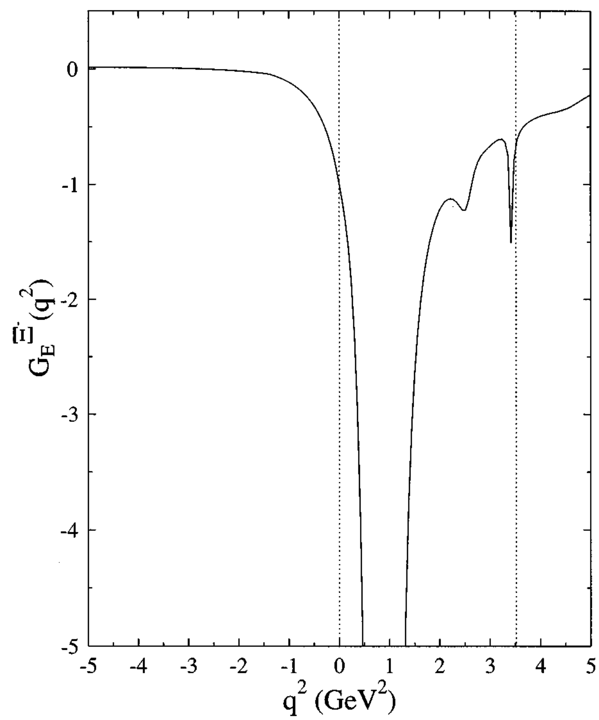

FIG. 17. Ξ^- electric form factor, $G_E^{\Xi^-}$.

(perturbative) modes. The dip effect arises from interference between the ρ,ω mesons and the excited resonances (especially the ϕ meson). The ρ and ω have a very steep q^2 dependence arising from their double pole structure (product of propagator and vertex form factor) whereas the excited resonances have terms involving the product of widely spaced single poles giving a much slower q^2 dependence. This dip feature is a consequence of our assumption that all of the vector mesons have the same vertex form factors. It seems likely that the excited vector resonances, which are breathing mode excited states, may have effective couplings to baryons which fall more rapidly as a function of q^2 than the corresponding ρ, ω, or ϕ ground states. With a more elaborate specification of vertex functions for the excited states, it is possible to eliminate the spacelike dip structures and also suppress the excited state contributions to the charge radius of each baryon.

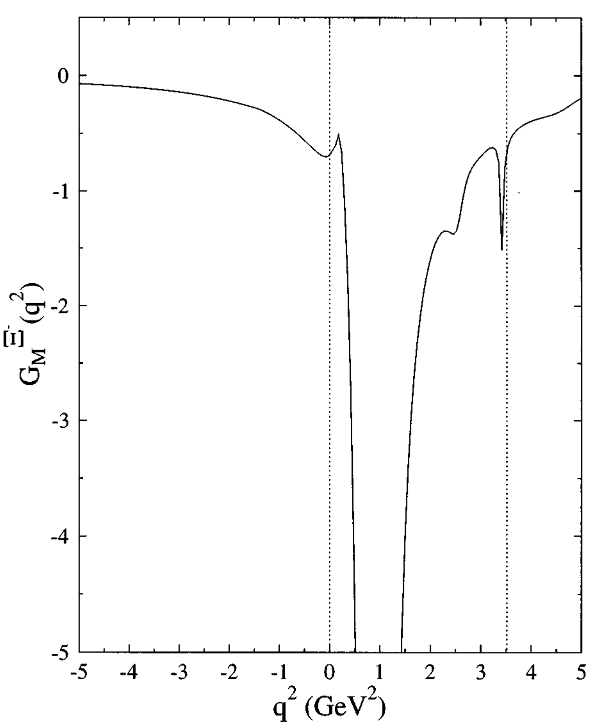

FIG. 16. Ξ^- magnetic form factor, $G_M^{\Xi^-}$.

IV. MEASURING HYPERON FORM FACTORS

A natural question is whether or not any of the electromagnetic hyperon form factors are measurable. Because it is not possible to construct a stable hyperon target, the only way to obtain a measurement is by some indirect method. The best possible situation would be to find some observable associated with electromagnetic hyperon production which is proportional to the unknown form factor. We have done a preliminary investigation based on model calculations of the $p(e,e'K^+)\vec{\Lambda},\vec{\Sigma}^0$ reactions [22] from which we identified qualitative signatures suggesting that the hyperon polarization at a large kaon angle is sensitive to the hyperon form factors. Specifically, we have found that the $\vec{\Lambda}$ polarization angular distribution is peaked at large $|t|$ independent of energy. Furthermore, the magnitude of the polarization goes through local maxima at energies ($\sqrt{s}$) equal to the masses of the N^* resonances. Since the hyperon polarization is an interference observable proportional to the imaginary part of the product of two amplitudes, we can interpret the behavior of the hyperon polarization energy and angular dependence as a signature of strong interference between the s-channel N^* resonances and the purely real u-channel Λ (Born) amplitude. The choice of large-$|t|$ kinematics suppresses competing t-channel mechanisms and enhances the production via intermediate state Λ propagation. A more extensive analysis is required to understand the role of competing mechanisms such as the effect of K^* amplitudes, however if our interpretation is correct then we have identified an experimental signature for an observable which is directly proportional to the magnetic Λ form factor. We propose that angular distribution measurements of $\vec{\Lambda}$ and $\vec{\Sigma}^0$ polarizations should be performed at an energy of a narrow N^* resonance to verify the large-$|t|$ (small-$|u|$) peak signature. Since the hyperon polarization is also directly proportional to the $N^*\gamma N$ transition form factor(s), the absolute normalizations of G_M^Λ and $G_M^{\Sigma\Lambda}$ cannot be determined by this method. However, we submit that tandem measurements of both $\vec{\Lambda}$ and $\vec{\Sigma}^0$ polarizations can be used to form a ratio which is independent of the $N^*\gamma N$ transition form factor. To avoid ambiguity, we write the following relation which appears to be valid within the framework of a realistic phenomenological model of kaon electroproduction:

$$\frac{G_M^\Lambda(q^2)}{G_M^{\Sigma\Lambda}(q^2)} \approx \alpha \frac{\mathscr{P}_\Lambda(q^2, \sqrt{s} = M_{N^*}, \theta_{\text{c.m.}} \sim 150°)}{\mathscr{P}_\Sigma(q^2, \sqrt{s} = M_{N^*}, \theta_{\text{c.m.}} \sim 150°)}. \tag{40}$$

The proportionality constant α can be fixed by one photoproduction ($q^2 = 0$) measurement of $\vec{\Lambda}$ and $\vec{\Sigma}$ polarizations. Theoretically, this ratio is very interesting because the Λ form factor has only isoscalar current contributions whereas the Σ-Λ transition form factor depends only on isovector currents. Hence this ratio would be very useful for seeing explicit strangeness and OZI effects such as the suppression or enhancement of effective ρ, ω, and ϕ vector meson–hyperon couplings [relative to the vector meson–nucleon couplings and $SU(3)_F$ symmetry predictions].

V. CONCLUSIONS

We have developed a unified model for the electromagnetic form factors of the octet baryons based on an extended, hybrid vector dominance formalism. All of the form factors are calculated with parameters which are determined completely from nucleon data together with theoretical constraints provided by an extension of Sakurai's universality hypothesis and the empirical OZI rule. Our version of universality constrains the effective vector meson couplings to obey sum rules which are satisfied by our model parameters. Theoretical interest in the hyperon form factors centers on determining the effects of explicit and hidden strangeness on electromagnetic observables, and testing the OZI rule in effective meson-nucleon interactions. We submit that it is feasible to extract $G_M^\Lambda(q^2)/G_M^{\Sigma\Lambda}(q^2)$ by measuring the q^2 variation in the backward kaon angle Λ/Σ polarization ratio. Additional analysis and discussion of this proceedure will be presented in a future paper.

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