EM STRUCTURE MODEL OF HYPERONS WITH GROUD STATE $\rho(770), \omega(782), \phi(1020)$ UNIVERSAL COUPLING CONSTANTS

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September 20, 2015

School/Workshop on Nuclear Physics'15, Erice, 16.-24. Sept. 2015

Outline

INTRODUCTION

According to $SU(3)$ classification of hadrons all $1/2^+$ hyperons are members of the $1/2^+$ baryon octet

$p, n, \Lambda, \Sigma^+, \Sigma^0, \Sigma^-, \Xi^0, \Xi^-$.

The electromagnetic (EM) structure of every of these particles is completely described by corresponding
electric $G_E(t)$
and **magnetic** $G_M(t)$
form factors (FFs), where $t = -Q^2$ is **squared momentum transferred by the virtual photon** γ^*.

INTRODUCTION

The FFs $G_E(t)$ and $G_M(t)$ are directly connected:

I.

with **experimentally measurable differential cross-section** of the elastic scattering of unpolarized electrons on unpolarized baryons $e^- B \to e^- B$ by the relation

$$\frac{d\sigma^{lab}(e^- B \to e^- B)}{d\Omega} = \frac{\alpha^2}{4E^2} \frac{cos^2(\theta/2)}{sin^4(\theta/2)} \frac{1}{1 + (\frac{2E}{m_B}) sin^2(\theta/2)}$$
$$\times [\frac{G_E^2(t) - \frac{t}{4m_B^2} G_M^2(t)}{1 - \frac{t}{4m_B^2}} - 2\frac{t}{4m_B^2} G_M^2(t) tan^2(\theta/2)] \qquad (1)$$

where $\alpha = 1/137$ is the fine structure constant, E is the incident electron energy and θ is scattering angle

INTRODUCTION

Ia.
the **specific measurement is the elastic scattering of the hyperon on atomic electrons**, by means of which the radius of the hyperon (i.e. Σ^--hyperon) can be in principle determined.

INTRODUCTION

II.

with **experimentally measurable total cross-section** of electron-positron annihilation into baryon-antibaryon $e^+e^- \to B\bar{B}$ by the relation

$$\sigma_{tot}^{c.m.}(e^+e^- \to B\bar{B}) = \frac{4\pi\alpha^2\beta_B}{3t}[\mid G_M(t) \mid^2 + \frac{2m_B^2}{t} \mid G_E(t) \mid^2] \quad (2)$$

where $\beta_B = \sqrt{1 - \frac{4m_B^2}{t}}$

INTRODUCTION

III.

with **experimentally measurable total cross-section** of antibaryon-baryon annihilation into electron-positron pair $\bar{B}B \to e^+e^-$ by the relation

$$\sigma_{tot}^{c.m.}(\bar{B}B \to e^+e^-) = \frac{2\pi\alpha^2}{3p_{c.m.}\sqrt{t}}[\mid G_M(t) \mid^2 + \frac{2m_B^2}{t} \mid G_E(t) \mid^2] \tag{3}$$

where $p_{c.m.}$ is the antibaryon momentum in the c.m. system

INTRODUCTION

IV.

with **experimentally measurable transverse** component

$$P_t = \frac{h}{I_0}(-2)\sqrt{\tau(1+\tau)}G_E(t)G_M(t)tan(\theta/2) \tag{4}$$

and **longitudinal** component

$$P_l = \frac{h(E+E')}{I_0 m_B}\sqrt{\tau(1+\tau)}G_M^2(t)tan^2(\theta/2) \tag{5}$$

of the **recoil baryon's polarization** in the electron scattering plane of the **polarization transfer process** $\vec{e}^- B \to e^- \vec{B}$ where h is the electron **beam helicity**, I_0 is the **unpolarized cross-section excluding** σ_{Mott} and $\tau = \frac{Q^2}{4m_B^2}$.

INTRODUCTION

By measuring P_t and P_l **simultaneously** one can obtain experimental information on the ratio

$$\mu_B \frac{G_E(t)}{G_M(t)} = -\frac{P_t}{P_l}\frac{E+E'}{2m_B} tan(\theta/2). \tag{6}$$

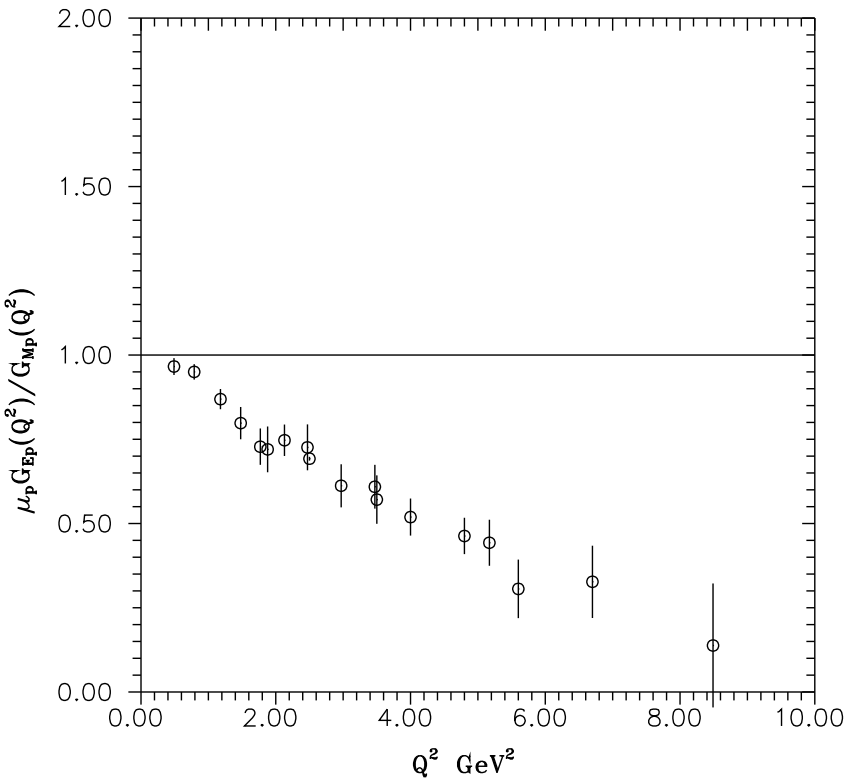
NOTE:
Due to the problem with hyperon targets - the measurements I., III. and IV. for **HYPERONS** are excluded!

The most data on electric and magnetic FFs, by means of the above mentioned experimentally measurable quantities, exist **for the proton**, and to some extent also **for the neutron to be obtained by light nuclei targets**.

Experimental status on protons and neutrons

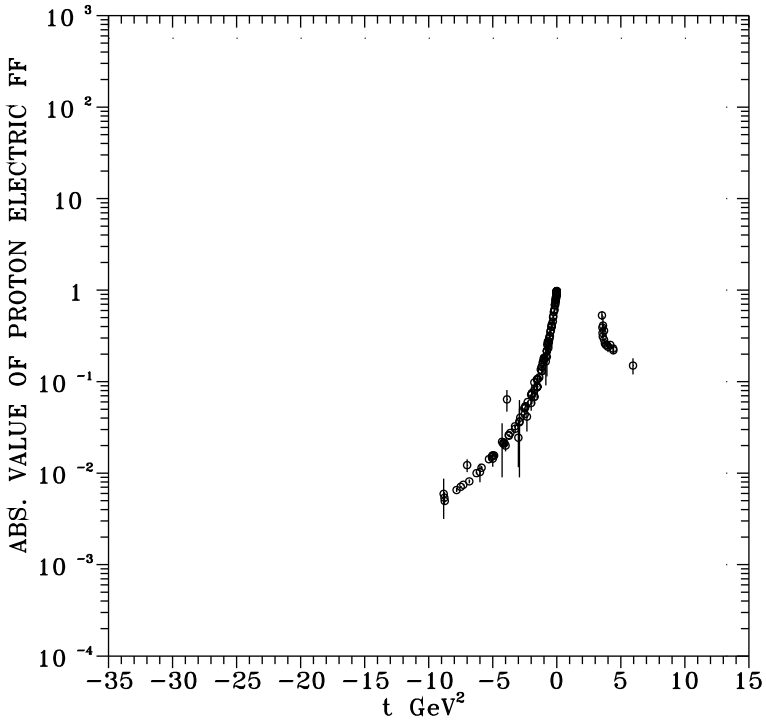
Present-day experimental information on the nucleon EM FFs $G_E^p(t)$ $G_M^p(t)$, $G_E^n(t)$, $G_M^n(t)$ consists of **10 different sets of data in various regions** - they are graphically presented in the following Figs.

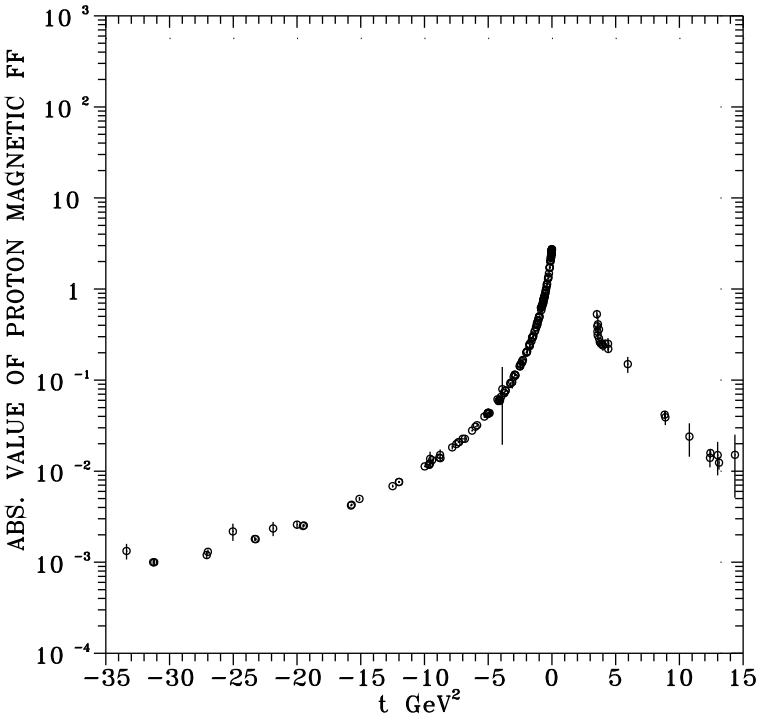
Experimental status on protons and neutrons



New JLab proton polarization data on the **ratio** $\mu_p G_E^p(t)/G_M^p(t)$, which **clearly demonstrate violation of the dipole behavior of** $G_E^p(t)$ **in space-like region**.

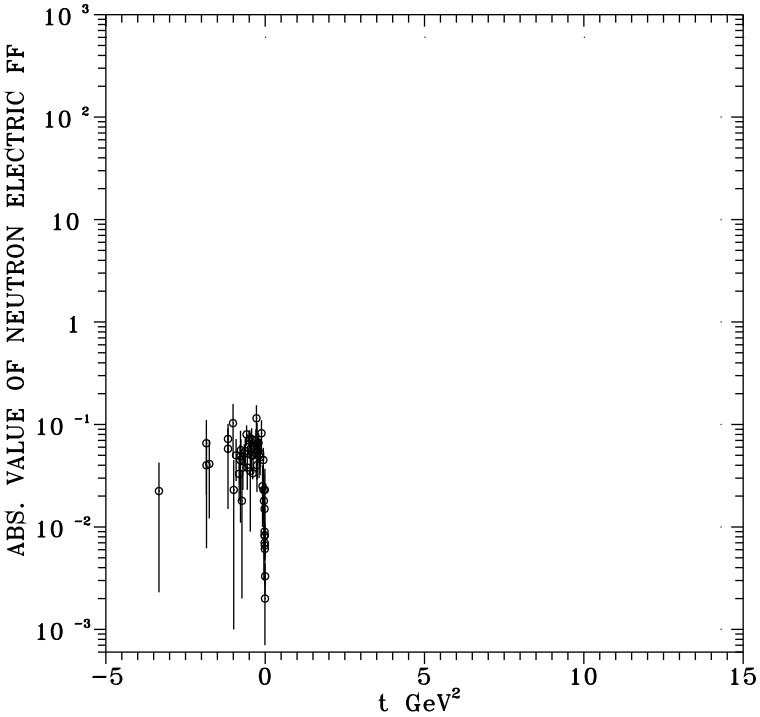
Experimental status on protons and neutrons

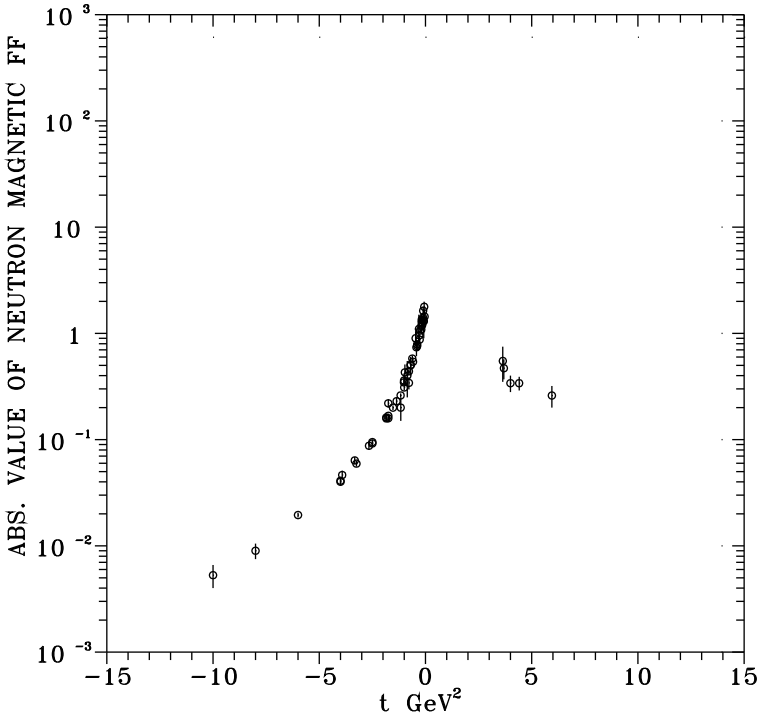




Experimental data on **proton electric and magnetic FFs** in space-like and time-like regions.

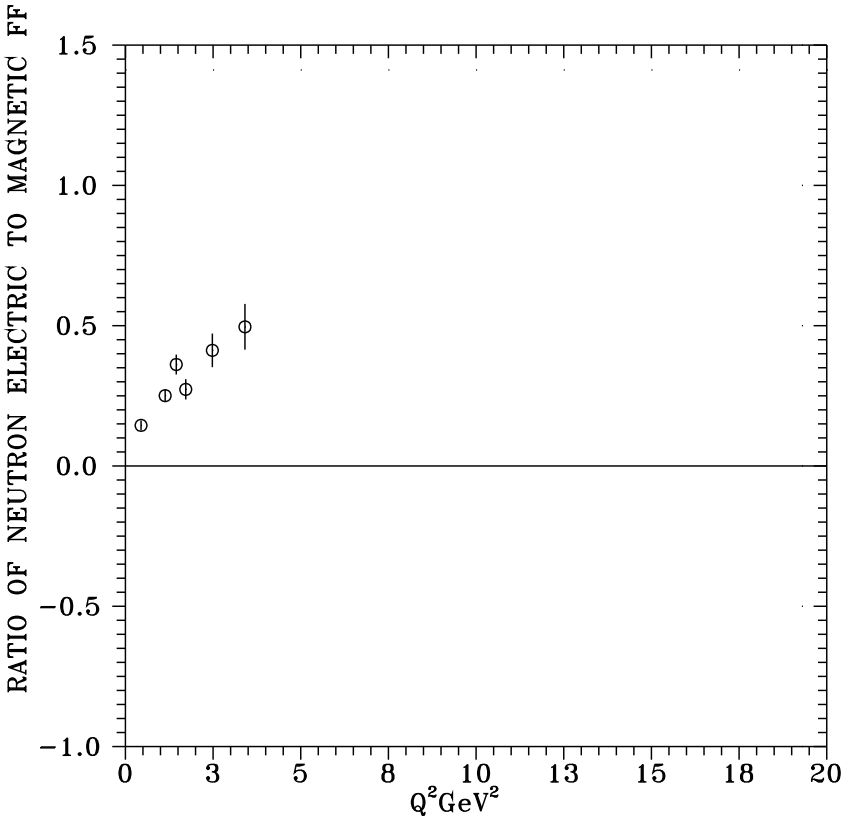
Experimental status on protons and neutrons





Experimental data on **neutron electric and magnetic FFs** in space-like and time-like regions.

Experimental status on protons and neutrons



Neutron polarization data on the **ratio** $\mu_n G_E^n(t)/G_M^n(t)$.

U&A MODEL OF $1/2^+$ OCTET BARYON EM STRUCTURE

In a construction of the *U&A* MODEL OF $1/2^+$ OCTET BARYON EM STRUCTURE **we shall apply the** *U&A* **approach**, which already appeared to be **very powerful in a description of the EM structure of the complete nonet of psedoscalar mesons** $\pi^-, \pi^0, \pi^+, K^-, K^0, \bar{K}^0, K^+, \eta, \eta'$

S.Dubnicka and A.Z.Dubnickova: Eur. Phys. J. Web of Conference 37 (2012) 01003

and to some extent also in a **description of the EM structure of vector meson nonet**
$\rho^-, \rho^0, \rho^+, K^{*-}, K^{*0}, \bar{K}^{*0}, K^{*+}, \omega, \phi$

C.Adamuscin, S.Dubnicka and A.Z.Dubnickova: contribution to MESON'14 Conference

U&A MODEL OF $1/2^+$ OCTET BARYON EM STRUCTURE

The model **respects all known theoretical properties** of the baryon EM FFs, like
- assumed analyticity
- unitarity conditions
- normalizations
- experimental fact of a creation of vector-meson resonances in e^+e^--annihilation processes into hadrons - **to every vector meson under consideration correspond a complex conjugate pair of poles placed always on un-physical sheets**
- and asymtotic behaviors

U&A MODEL OF $1/2^+$ OCTET BARYON EM STRUCTURE

Electric and magnetic FFs, $G_E(t)$ and $G_M(t)$, - **very suitable for extraction of experimental data** from the measured physical quantities.

However, for construction of various baryon EM structure models the flavor-independent **iso-scalar and iso-vector parts** of the **Dirac and Pauli FFs** to be defined by a parametrization of the baryon EM current

$$< B \mid J_\mu^{EM} \mid B >= \bar{u}(p')\{\gamma_\mu F_1^B(t) + i\frac{\sigma_{\mu\nu}q_\nu}{2m_B^2}F_2^B(t)\}u(p) \qquad (7)$$

are more suitable.

U&A MODEL OF $1/2^+$ OCTET BARYON EM STRUCTURE

Both **sets of FFs are related**

$$G_E^p(t) = [F_{1s}^N(t) + F_{1v}^N(t)] + \frac{t}{4m_p^2}[F_{2s}^N(t) + F_{2v}^N(t)]$$
$$G_M^p(t) = [F_{1s}^N(t) + F_{1v}^N(t)] + [F_{2s}^N(t) + F_{2v}^N(t)]$$
$$G_E^n(t) = [F_{1s}^N(t) - F_{1v}^N(t)] + \frac{t}{4m_n^2}[F_{2s}^N(t) - F_{2v}^N(t)]$$
$$G_M^n(t) = [F_{1s}^N(t) - F_{1v}^N(t)] + [F_{2s}^N(t) - F_{2v}^N(t)]$$
$$G_E^\Lambda(t) = F_{1s}^\Lambda(t) + \frac{t}{4m_\Lambda^2}F_{2s}^\Lambda(t)$$
$$G_M^\Lambda(t) = F_{1s}^\Lambda(t) + F_{2s}^\Lambda(t)$$
$$G_E^{\Sigma^0}(t) = F_{1s}^\Sigma(t) + \frac{t}{4m_\Sigma^2}F_{2s}^\Sigma(t)$$
$$G_M^{\Sigma^0}(t) = F_{1s}^\Sigma(t) + F_{2s}^\Sigma(t)$$

U&A MODEL OF $1/2^+$ OCTET BARYON EM STRUCTURE

$$G_E^{\Sigma^+,\Sigma^-}(t) = [F_{1s}^{\Sigma}(t) \pm F_{1v}^{\Sigma}(t)] + \frac{t}{4m_{\Sigma}^2}[F_{2s}^{\Sigma}(t) \pm F_{2v}^{\Sigma}(t)]$$
$$G_M^{\Sigma^+,\Sigma^-}(t) = [F_{1s}^{\Sigma}(t) \pm F_{1v}^{\Sigma}(t)] + [F_{2s}^{\Sigma}(t) \pm F_{2v}^{\Sigma}(t)]$$
$$G_E^{\Xi^0,\Xi^-}(t) = [F_{1s}^{\Xi}(t) \pm F_{1v}^{\Xi}(t)] + \frac{t}{4m_{\Xi}^2}[F_{2s}^{\Xi}(t) \pm F_{2v}^{\Xi}(t)]$$
$$G_M^{\Xi^0,\Xi^-}(t) = [F_{1s}^{\Xi}(t) \pm F_{1v}^{\Xi}(t)] + [F_{2s}^{\Xi}(t) \pm F_{2v}^{\Xi}(t)].$$

U&A MODEL OF $1/2^+$ OCTET BARYON EM STRUCTURE

whereby **experimental fact of a creation of vector-meson resonances in** $e^+e^- \to had$ is taken into account:

- **in saturation of** $F^s_{1B}(t), F^s_{2B}(t)$ **by iso-scalar vector mesons**
- **in saturation of** $F^v_{1B}(t), F^v_{2B}(t)$ **by iso-vector vector meson resonances**

in the corresponding **zero width approximation** of *VMD* parametrizations.

U&A MODEL OF $1/2^+$ OCTET BARYON EM STRUCTURE

Consideration of the $SU(3)$ symmetry in EM structure model means - **always complete trinity of vector-mesons ($\rho, \omega, \phi; \rho', \omega', \phi'$; etc.) has to be taken into account** !

The **Review of Particle Physics**

J.Beringer et al (Particle Data Group), Phys. Rev. D86 (2012) 010001.

provides **just 3 complete trinities of such vector-meson resonances**

$\rho(770), \omega(782), \phi(1020)$
$\omega'(1420), \rho'(1450)), \phi'(1680)$
$\omega''(1650), \rho''(1700), \phi''(2170)$.
then also **OZI rule violation is fulfilled**.

U&A MODEL OF NUCLEON EM STRUCTURE

Then starting point of a construction of the *U&A* model is 9-**resonance (3 iso-vectors and 6 iso-scalars)** *VMD* **model**

$$F_{1s}^{N}(t) = \frac{1}{2}\frac{m_\omega^2 m_\phi^2}{(m_\omega^2 - t)(m_\phi^2 - t)} +$$

$$+\left\{\frac{m_\phi^2 m_{\omega'}^2}{(m_\phi^2 - t)(m_{\omega'}^2 - t)}\frac{(m_\phi^2 - m_{\omega'}^2)}{(m_\phi^2 - m_\omega^2)} + \frac{m_\omega^2 m_{\omega'}^2}{(m_\omega^2 - t)(m_{\omega'}^2 - t)}\frac{(m_\omega^2 - m_{\omega'}^2)}{(m_\omega^2 - m_\phi^2)} - \right.$$

$$\left. - \frac{m_\omega^2 m_\phi^2}{(m_\omega^2 - t)(m_\phi^2 - t)}\right\}(f_{\omega' NN}^{(1)}/f_{\omega'}) +$$

$$+\left\{\frac{m_\phi^2 m_{\phi'}^2}{(m_\phi^2 - t)(m_{\phi'}^2 - t)}\frac{(m_\phi^2 - m_{\phi'}^2)}{(m_\phi^2 - m_\omega^2)} + \frac{m_\omega^2 m_{\phi'}^2}{(m_\omega^2 - t)(m_{\phi'}^2 - t)}\frac{(m_\omega^2 - m_{\phi'}^2)}{(m_\omega^2 - m_\phi^2)} - \right.$$

$$\left. - \frac{m_\omega^2 m_\phi^2}{(m_\omega^2 - t)(m_\phi^2 - t)}\right\}(f_{\phi' NN}^{(1)}/f_{\phi'}) +$$

U&A MODEL OF NUCLEON EM STRUCTURE

$$+\left\{\frac{m_\phi^2 m_{\omega''}^2}{(m_\phi^2-t)(m_{\omega''}^2-t)}\frac{(m_\phi^2-m_{\omega''}^2)}{(m_\phi^2-m_\omega^2)}+\frac{m_\omega^2 m_{\omega''}^2}{(m_\omega^2-t)(m_{\omega''}^2-t)}\frac{(m_\omega^2-m_{\omega''}^2)}{(m_\omega^2-m_\phi^2)}-\right.$$

$$\left.-\frac{m_\omega^2 m_\phi^2}{(m_\omega^2-t)(m_\phi^2-t)}\right\}(f^{(1)}_{\omega'' NN}/f_{\omega''})+$$

$$+\left\{\frac{m_\phi^2 m_{\phi''}^2}{(m_\phi^2-t)(m_{\phi''}^2-t)}\frac{(m_\phi^2-m_{\phi''}^2)}{(m_\phi^2-m_\omega^2)}+\frac{m_\omega^2 m_{\phi''}^2}{(m_\omega^2-t)(m_{\phi''}^2-t)}\frac{(m_\omega^2-m_{\phi''}^2)}{(m_\omega^2-m_\phi^2)}-\right.$$

$$\left.-\frac{m_\omega^2 m_\phi^2}{(m_\omega^2-t)(m_\phi^2-t)}\right\}(f^{(1)}_{\phi'' NN}/f_{\phi''}).$$

U&A MODEL OF NUCLEON EM STRUCTURE

$$F_{1v}^{N}(t) = \frac{1}{2}\frac{m_\rho^2 m_{\rho'}^2}{(m_\rho^2 - t)(m_{\rho'}^2 - t)} +$$

$$+\left\{\frac{m_{\rho'}^2 m_{\rho''}^2}{(m_{\rho'}^2 - t)(m_{\rho''}^2 - t)}\frac{(m_{\rho'}^2 - m_{\rho''}^2)}{(m_{\rho'}^2 - m_\rho^2)} + \frac{m_\rho^2 m_{\rho''}^2}{(m_\rho^2 - t)(m_{\rho''}^2 - t)}\frac{(m_\rho^2 - m_{\rho''}^2)}{(m_\rho^2 - m_{\rho'}^2)} - \right.$$

$$\left. - \frac{m_\rho^2 m_{\rho'}^2}{(m_\rho^2 - t)(m_{\rho'}^2 - t)}\right\}(f_{\rho'' NN}^{(1)}/f_{\rho''}).$$

U&A MODEL OF NUCLEON EM STRUCTURE

$$
\begin{aligned}
F_{2s}^{N}(t) = \frac{1}{2}(\mu_p + \mu_n - 1)\frac{m_\omega^2 m_\phi^2 m_{\omega'}^2}{(m_\omega^2 - t)(m_\phi^2 - t)(m_{\omega'}^2 - t)} + \\
+\left\{ \frac{m_\phi^2 m_{\omega'}^2 m_{\phi'}^2}{(m_\phi^2 - t)(m_{\omega'}^2 - t)(m_{\phi'}^2 - t)} \frac{(m_\phi^2 - m_{\phi'}^2)(m_{\omega'}^2 - m_{\phi'}^2)}{(m_\phi^2 - m_\omega^2)(m_{\omega'}^2 - m_\omega^2)} + \right. \\
+\frac{m_\omega^2 m_{\omega'}^2 m_{\phi'}^2}{(m_\omega^2 - t)(m_{\omega'}^2 - t)(m_{\phi'}^2 - t)} \frac{(m_\omega^2 - m_{\phi'}^2)(m_{\omega'}^2 - m_{\phi'}^2)}{(m_\omega^2 - m_\phi^2)(m_{\omega'}^2 - m_\phi^2)} + \\
+\frac{m_\omega^2 m_\phi^2 m_{\phi'}^2}{(m_\omega^2 - t)(m_\phi^2 - t)(m_{\phi'}^2 - t)} \frac{(m_\omega^2 - m_{\phi'}^2)(m_\phi^2 - m_{\phi'}^2)}{(m_\omega^2 - m_{\omega'}^2)(m_\phi^2 - m_{\omega'}^2)} - \\
\left. - \frac{m_\omega^2 m_\phi^2 m_{\omega'}^2}{(m_\omega^2 - t)(m_\phi^2 - t)(m_{\omega'}^2 - t)} \right\} (f_{\phi' NN}^{(2)}/f_{\phi'}) +
\end{aligned}
$$

U&A MODEL OF NUCLEON EM STRUCTURE

$$
+\left\{\frac{m_\phi^2 m_{\omega'}^2 m_{\omega''}^2}{(m_\phi^2-t)(m_{\omega'}^2-t)(m_{\omega''}^2-t)}\frac{(m_\phi^2-m_{\omega''}^2)(m_{\omega'}^2-m_{\omega''}^2)}{(m_\phi^2-m_\omega^2)(m_{\omega'}^2-m_\omega^2)}+\right.
$$

$$
+\frac{m_\omega^2 m_{\omega'}^2 m_{\omega''}^2}{(m_\omega^2-t)(m_{\omega'}^2-t)(m_{\omega''}^2-t)}\frac{(m_\omega^2-m_{\omega''}^2)(m_{\omega'}^2-m_{\omega''}^2)}{(m_\omega^2-m_\phi^2)(m_{\omega'}^2-m_\phi^2)}+
$$

$$
+\frac{m_\omega^2 m_\phi^2 m_{\omega''}^2}{(m_\omega^2-t)(m_\phi^2-t)(m_{\omega''}^2-t)}\frac{(m_\omega^2-m_{\omega''}^2)(m_\phi^2-m_{\omega''}^2)}{(m_\omega^2-m_{\omega'}^2)(m_\phi^2-m_{\omega'}^2)}-
$$

$$
\left.-\frac{m_\omega^2 m_\phi^2 m_{\omega'}^2}{(m_\omega^2-t)(m_\phi^2-t)(m_{\omega'}^2-t)}\right\}(f^{(2)}_{\omega''NN}/f_{\omega''})+
$$

U&A MODEL OF NUCLEON EM STRUCTURE

$$
\begin{aligned}
&+\left\{\frac{m_\phi^2 m_{\omega'}^2 m_{\phi''}^2}{(m_\phi^2-t)(m_{\omega'}^2-t)(m_{\phi''}^2-t)}\frac{(m_\phi^2-m_{\phi''}^2)(m_{\omega'}^2-m_{\phi''}^2)}{(m_\phi^2-m_\omega^2)(m_{\omega'}^2-m_\omega^2)}+\right.\\
&+\frac{m_\omega^2 m_{\omega'}^2 m_{\phi''}^2}{(m_\omega^2-t)(m_{\omega'}^2-t)(m_{\phi''}^2-t)}\frac{(m_\omega^2-m_{\phi''}^2)(m_{\omega'}^2-m_{\phi''}^2)}{(m_\omega^2-m_\phi^2)(m_{\omega'}^2-m_\phi^2)}+\\
&+\frac{m_\omega^2 m_\phi^2 m_{\phi''}^2}{(m_\omega^2-t)(m_\phi^2-t)(m_{\phi''}^2-t)}\frac{(m_\omega^2-m_{\phi''}^2)(m_\phi^2-m_{\phi''}^2)}{(m_\omega^2-m_{\omega'}^2)(m_\phi^2-m_{\omega'}^2)}-\\
&\left.-\frac{m_\omega^2 m_\phi^2 m_{\omega'}^2}{(m_\omega^2-t)(m_\phi^2-t)(m_{\omega'}^2-t)}\right\}(f^{(2)}_{\phi'' NN}/f_{\phi''})
\end{aligned}
$$

U&A MODEL OF NUCLEON EM STRUCTURE

$$F_{2v}^{N}(t) = \frac{1}{2}(\mu_p - \mu_n - 1)\frac{m_\rho^2 m_{\rho'}^2 m_{\rho''}^2}{(m_\rho^2 - t)(m_{\rho'}^2 - t)(m_{\rho''}^2 - t)}$$

to be **automatically normalized** and governing the **asymptotic behaviors** as predicted by the quark model of hadrons.

By the non-linear transformations

$$t = t_0^s + \frac{4(t_{in}^{1s} - t_0^s)}{[1/V(t) - V(t)]^2}; \quad t = t_0^v + \frac{4(t_{in}^{1v} - t_0^v)}{[1/W(t) - W(t)]^2};$$

$$t = t_0^s + \frac{4(t_{in}^{2s} - t_0^s)}{[1/U(t) - U(t)]^2}; \quad t = t_0^v + \frac{4(t_{in}^{2v} - t_0^v)}{[1/X(t) - X(t)]^2}.$$

and a subsequent **inclusion of the nonzero values of vector-meson widths**, for every iso-scalar and iso-vector Dirac and Pauli FF, one obtains just **one analytic and smooth from** $-\infty$ **to** $+\infty$ **function** in the form

U&A MODEL OF NUCLEON EM STRUCTURE

$$F_{1s}^{N}[V(t)] = \left(\frac{1-V^2}{1-V_N^2}\right)^4 \frac{1}{2} L_\omega(V) L_\phi(V) +$$

$$+\left(\frac{1-V^2}{1-V_N^2}\right)^4 \left[L_\phi(V) L_{\omega'}(V) \frac{(C_\phi^{1s} - C_{\omega'}^{1s})}{(C_\phi^{1s} - C_\omega^{1s})} + L_\omega(V) L_{\omega'}(V) \frac{(C_\omega^{1s} - C_{\omega'}^{1s})}{(C_\omega^{1s} - C_\phi^{1s})} - \right.$$

$$\left. - L_\omega(V) L_\phi(V) \right] (f_{\omega' NN}^{(1)} / f_{\omega'}) +$$

$$+\left(\frac{1-V^2}{1-V_N^2}\right)^4 \left[L_\phi(V) H_{\phi'}(V) \frac{(C_\phi^{1s} - C_{\phi'}^{1s})}{(C_\phi^{1s} - C_\omega^{1s})} + L_\omega(V) H_{\phi'}(V) \frac{(C_\omega^{1s} - C_{\phi'}^{1s})}{(C_\omega^{1s} - C_\phi^{1s})} - \right.$$

$$\left. - L_\omega(V) L_\phi(V) \right] (f_{\phi' NN}^{(1)} / f_{\phi'}) +$$

U&A MODEL OF NUCLEON EM STRUCTURE

$$+\left(\frac{1-V^2}{1-V_N^2}\right)^4\left[L_\phi(V)H_{\omega''}(V)\frac{(C_\phi^{1s}-C_{\omega''}^{1s})}{(C_\phi^{1s}-C_\omega^{1s})}+L_\omega(V)H_{\omega''}(V)\frac{(C_\omega^{1s}-C_{\omega''}^{1s})}{(C_\omega^{1s}-C_\phi^{1s})}-\right.$$

$$\left.-L_\omega(V)L_\phi(V)\right](f^{(1)}_{\omega''NN}/f_{\omega''})+$$

$$+\left(\frac{1-V^2}{1-V_N^2}\right)^4\left[L_\phi(V)H_{\phi''}(V)\frac{(C_\phi^{1s}-C_{\phi''}^{1s})}{(C_\phi^{1s}-C_\omega^{1s})}+L_\omega(V)H_{\phi''}(V)\frac{(C_\omega^{1s}-C_{\phi''}^{1s})}{(C_\omega^{1s}-C_\phi^{1s})}-\right.$$

$$\left.-L_\omega(V)L_\phi(V)\right](f^{(1)}_{\phi''NN}/f_{\phi''})$$

U&A MODEL OF NUCLEON EM STRUCTURE

$$F_{1v}^{N}[W(t)] = \left(\frac{1-W^2}{1-W_N^2}\right)^4 \left\{ \frac{1}{2} L_\rho(W) L_{\rho'}(W) + \right.$$

$$+ \left[L_{\rho'}(W) H_{\rho''}(W) \frac{(C_{\rho'}^{1v} - C_{\rho''}^{1v})}{(C_{\rho'}^{1v} - C_{\rho}^{1v})} + L_\rho(W) H_{\rho''}(W) \frac{(C_{\rho}^{1v} - C_{\rho''}^{1v})}{(C_{\rho}^{1v} - C_{\rho'}^{1v})} - \right.$$

$$\left. \left. - L_\rho(W) L_{\rho'}(W) \right] (f_{\rho'' NN}^{(1)} / f_{\rho''}) \right\}$$

U&A MODEL OF NUCLEON EM STRUCTURE

$$F_{2s}^{N}[U(t)] = \left(\frac{1-U^2}{1-U_N^2}\right)^6 \frac{1}{2}(\mu_p + \mu_n - 1) L_\omega(U) L_\phi(U) L_{\omega'}(U) +$$

$$+\left(\frac{1-U^2}{1-U_N^2}\right)^6 \Bigg[L_\phi(U) L_{\omega'}(U) H_{\phi'}(U) \frac{(C_\phi^{2s} - C_{\phi'}^{2s})(C_{\omega'}^{2s} - C_{\phi'}^{2s})}{(C_\phi^{2s} - C_\omega^{2s})(C_{\omega'}^{2s} - C_\omega^{2s})} +$$

$$+ L_\omega(U) L_{\omega'}(U) H_{\phi'}(U) \frac{(C_\omega^{2s} - C_{\phi'}^{2s})(C_{\omega'}^{2s} - C_{\phi'}^{2s})}{(C_\omega^{2s} - C_\phi^{2s})(C_{\omega'}^{2s} - C_\phi^{2s})} +$$

$$+ L_\omega(U) L_\phi(U) H_{\phi'}(U) \frac{(C_\omega^{2s} - C_{\phi'}^{2s})(C_\phi^{2s} - C_{\phi'}^{2s})}{(C_\omega^{2s} - C_{\omega'}^{2s})(C_\phi^{2s} - C_{\omega'}^{2s})} -$$

$$- L_\omega(U) L_\phi(U) L_{\omega'}(U) \Bigg] (f_{\phi' NN}^{(2)} / f_{\phi'}) +$$

U&A MODEL OF NUCLEON EM STRUCTURE

$$+\left(\frac{1-U^2}{1-U_N^2}\right)^6\Bigg[L_\phi(U)L_{\omega'}(U)H_{\omega''}(U)\frac{(C_\phi^{2s}-C_{\omega''}^{2s})(C_{\omega'}^{2s}-C_{\omega''}^{2s})}{(C_\phi^{2s}-C_\omega^{2s})(C_{\omega'}^{2s}-C_\omega^{2s})}+$$

$$+L_\omega(U)L_{\omega'}(U)H_{\omega''}(U)\frac{(C_\omega^{2s}-C_{\omega''}^{2s})(C_{\omega'}^{2s}-C_{\omega''}^{2s})}{(C_\omega^{2s}-C_\phi^{2s})(C_{\omega'}^{2s}-C_\phi^{2s})}+$$

$$+L_\omega(U)L_\phi(U)H_{\omega''}(U)\frac{(C_\omega^{2s}-C_{\omega''}^{2s})(C_\phi^{2s}-C_{\omega''}^{2s})}{(C_\omega^{2s}-C_{\omega'}^{2s})(C_\phi^{2s}-C_{\omega'}^{2s})}-$$

$$-L_\omega(U)L_\phi(U)L_{\omega'}(U)\Bigg](f^{(2)}_{\omega''NN}/f_{\omega''})+$$

U&A MODEL OF NUCLEON EM STRUCTURE

$$
\begin{aligned}
+\left(\frac{1-U^2}{1-U_N^2}\right)^6 \Bigg[& L_\phi(U) L_{\omega'}(U) H_{\phi''}(U) \frac{(C_\phi^{2s} - C_{\phi''}^{2s})(C_{\omega'}^{2s} - C_{\phi''}^{2s})}{(C_\phi^{2s} - C_\omega^{2s})(C_{\omega'}^{2s} - C_\omega^{2s})} + \\
& + L_\omega(U) L_{\omega'}(U) H_{\phi''}(U) \frac{(C_\omega^{2s} - C_{\phi''}^{2s})(C_{\omega'}^{2s} - C_{\phi''}^{2s})}{(C_\omega^{2s} - C_\phi^{2s})(C_{\omega'}^{2s} - C_\phi^{2s})} + \\
& + L_\omega(U) L_\phi(U) H_{\phi''}(U) \frac{(C_\omega^{2s} - C_{\phi''}^{2s})(C_\phi^{2s} - C_{\phi''}^{2s})}{(C_\omega^{2s} - C_{\omega'}^{2s})(C_\phi^{2s} - C_{\omega'}^{2s})} - \\
& - L_\omega(U) L_\phi(U) L_{\omega'}(U) \Bigg] (f^{(2)}_{\phi'' NN} / f_{\phi''})
\end{aligned}
$$

U&A MODEL OF NUCLEON EM STRUCTURE

$$F_{2v}^{N}[X(t)] = \left(\frac{1-X^2}{1-X_N^2}\right)^6 \left\{\frac{1}{2}(\mu_p - \mu_n - 1)L_\rho(U)L_{\rho'}(U)H_{\rho''}(U)\right\}$$

where

$$L_r(V) = \frac{(V_N - V_r)(V_N - V_r^*)(V_N - 1/V_r)(V_N - 1/V_r^*)}{(V - V_r)(V - V_r^*)(V - 1/V_r)(V - 1/V_r^*)},$$

$$C_r^{1s} = \frac{(V_N - V_r)(V_N - V_r^*)(V_N - 1/V_r)(V_N - 1/V_r^*)}{-(V_r - 1/V_r)(V_r - 1/V_r^*)}, r = \omega, \phi, \omega'$$

U&A MODEL OF NUCLEON EM STRUCTURE

$$H_l(V) = \frac{(V_N - V_l)(V_N - V_l^*)(V_N + V_l)(V_N + V_l^*)}{(V - V_l)(V - V_l^*)(V + V_l)(V + V_l^*)},$$

$$C_l^{1s} = \frac{(V_N - V_l)(V_N - V_l^*)(V_N + V_l)(V_N + V_l^*)}{-(V_l - 1/V_l)(V_l - 1/V_l^*)}, l = \phi', \omega'' \phi''$$

$$L_k(W) = \frac{(W_N - W_k)(W_N - W_k^*)(W_N - 1/W_k)(W_N - 1/W_k^*)}{(W - W_k)(W - W_k^*)(W - 1/W_k)(W - 1/W_k^*)},$$

$$C_k^{1v} = \frac{(W_N - W_k)(W_N - W_k^*)(W_N - 1/W_k)(W_N - 1/W_k^*)}{-(W_k - 1/W_k)(W_k - 1/W_k^*)}, k = \rho, \rho'$$

U&A MODEL OF NUCLEON EM STRUCTURE

$$H_{\rho''}(W) = \frac{(W_N - W_{\rho''})(W_N - W^*_{\rho''})(W_N + W_{\rho''})(W_N + W^*_{\rho''})}{(W - W_{\rho''})(W - W^*_{\rho''})(W + W_{\rho''})(W + W^*_{\rho''})},$$

$$C^{1v}_{\rho''} = \frac{(W_N - W_{\rho''})(W_N - W^*_{\rho''})(W_N + W_{\rho''})(W_N + W^*_{\rho''})}{-(W_{\rho''} - 1/W_{\rho''})(W_{\rho''} - 1/W^*_{\rho''})},$$

$$L_r(U) = \frac{(U_N - U_r)(U_N - U^*_r)(U_N - 1/U_r)(U_N - 1/U^*_r)}{(U - U_r)(U - U^*_r)(U - 1/U_r)(U - 1/U^*_r)},$$

$$C^{2s}_r = \frac{(U_N - U_r)(U_N - U^*_r)(U_N - 1/U_r)(U_N - 1/U^*_r)}{-(U_r - 1/U_r)(U_r - 1/U^*_r)}, r = \omega, \phi, \omega'$$

$$H_l(U) = \frac{(U_N - U_l)(U_N - U^*_l)(U_N + U_l)(U_N + U^*_l)}{(U - U_l)(U - U^*_l)(U + U_l)(U + U^*_l)},$$

$$C^{2s}_l = \frac{(U_N - U_l)(U_N - U^*_l)(U_N + U_l)(U_N + U^*_l)}{-(U_l - 1/U_l)(U_l - 1/U^*_l)}, l = \phi', \omega'' \phi''$$

U&A MODEL OF NUCLEON EM STRUCTURE

$$L_k(X) = \frac{(X_N - X_k)(X_N - X_k^*)(X_N - 1/X_k)(X_N - 1/X_k^*)}{(X - X_k)(X - X_k^*)(X - 1/X_k)(X - 1/X_k^*)},$$

$$C_k^{2v} = \frac{(X_N - X_k)(X_N - X_k^*)(X_N - 1/X_k)(X_N - 1/X_k^*)}{-(X_k - 1/X_k)(X_k - 1/X_k^*)}, k = \rho, \rho'$$

$$H_{\rho''}(X) = \frac{(X_N - X_{\rho''})(X_N - X_{\rho''}^*)(X_N + X_{\rho''})(X_N + X_{\rho''}^*)}{(X - X_{\rho''})(X - X_{\rho''}^*)(X + X_{\rho''})(X + X_{\rho''}^*)},$$

$$C_{\rho''}^{2v} = \frac{(X_N - X_{\rho''})(X_N - X_{\rho''}^*)(X_N + X_{\rho''})(W_X + X_{\rho''}^*)}{-(X_{\rho''} - 1/X_{\rho''})(X_{\rho''} - 1/X_{\rho''}^*)}.$$

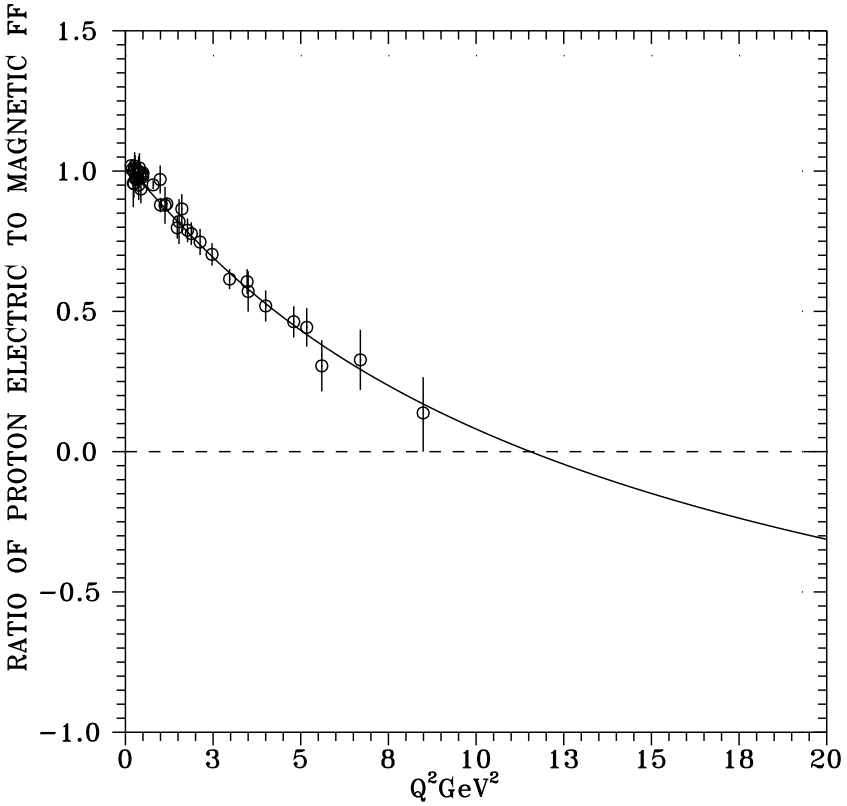
U&A MODEL OF NUCLEON EM STRUCTURE

This advanced model is **defined on four-sheeted Riemann surface** and one can simply verify that it includes all required properties like

- **experimental fact of a creation of unstable vector-meson resonances** in e^+e^- annihilation processes into hadrons
- the **analytic properties** of FFs
- the **reality conditions**
- **unitarity conditions** of FFs
- **normalizations** of FFs
- **asymptotic behaviors** of FFs as predicted by quark model of hadrons

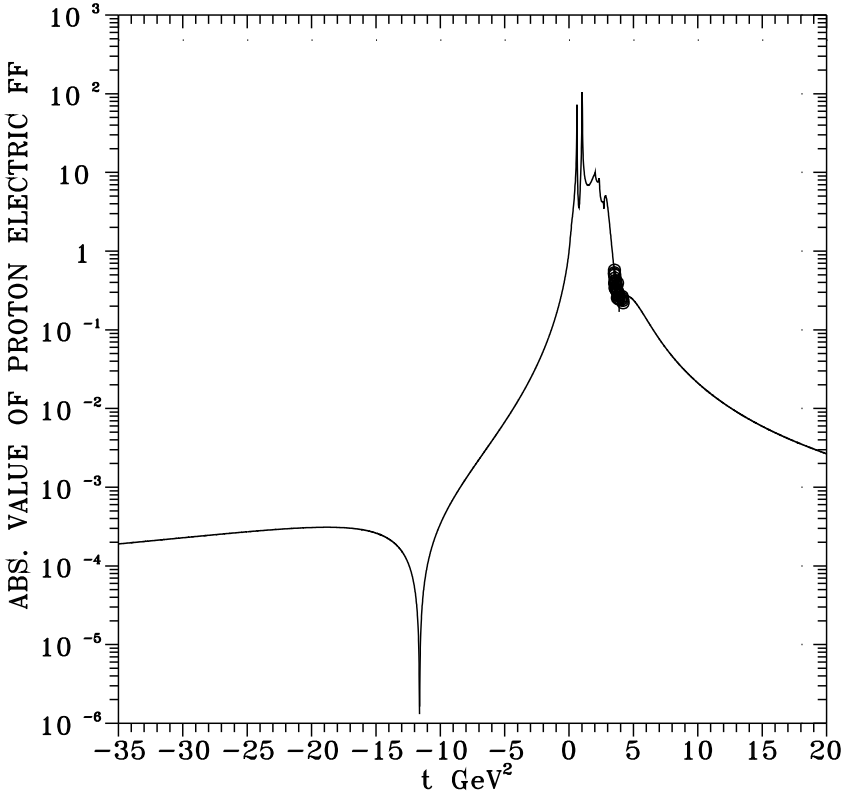
By its comparison with present-day nucleon EM FFs data in space-like and time-like regions simultaneously(see Figs.)

U&A MODEL OF NUCLEON EM STRUCTURE



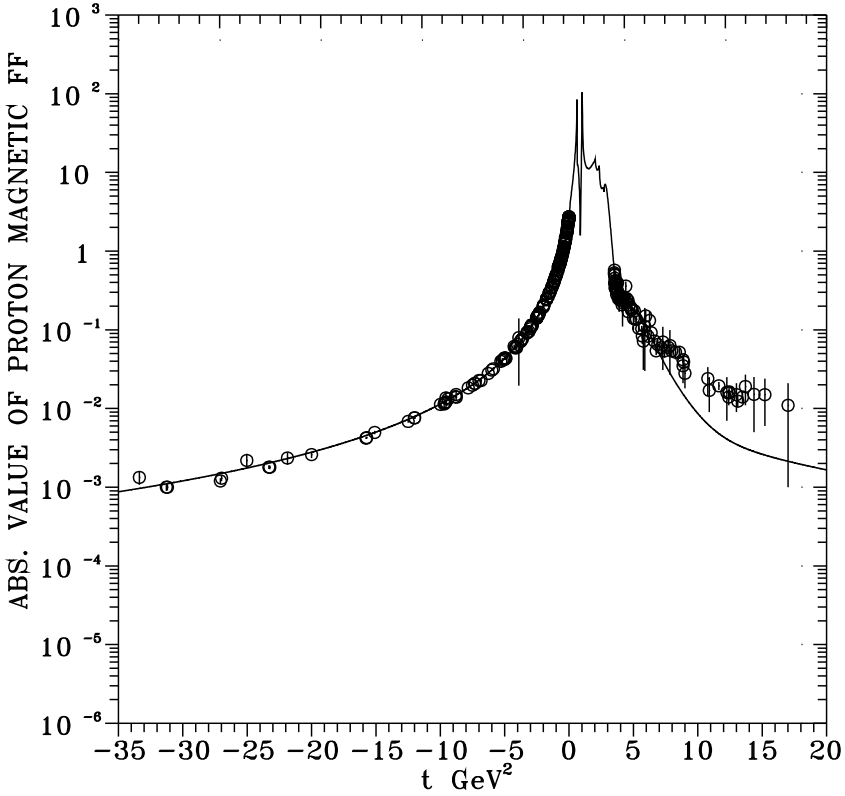
Prediction of **proton electric to magnetic FFs ratio** behavior by *U&A* model respecting *SU*(3) symmetry and OZI rule violation

U&A MODEL OF NUCLEON EM STRUCTURE



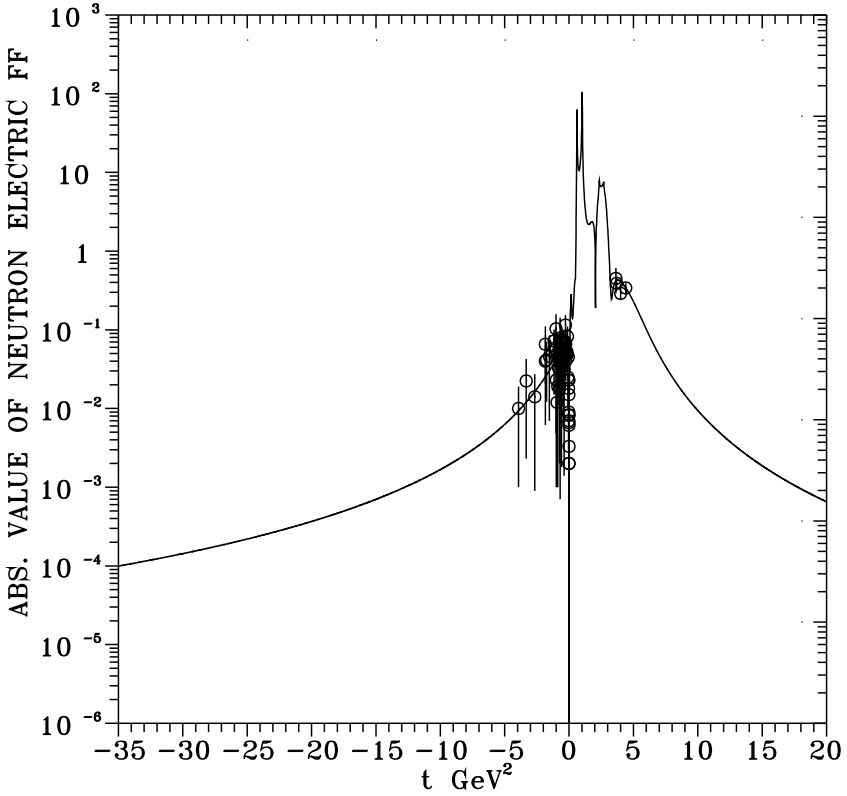
Prediction of **proton electric FF** behavior by *U&A* model respecting *SU*(3) symmetry and OZI rule violation

U&A MODEL OF NUCLEON EM STRUCTURE



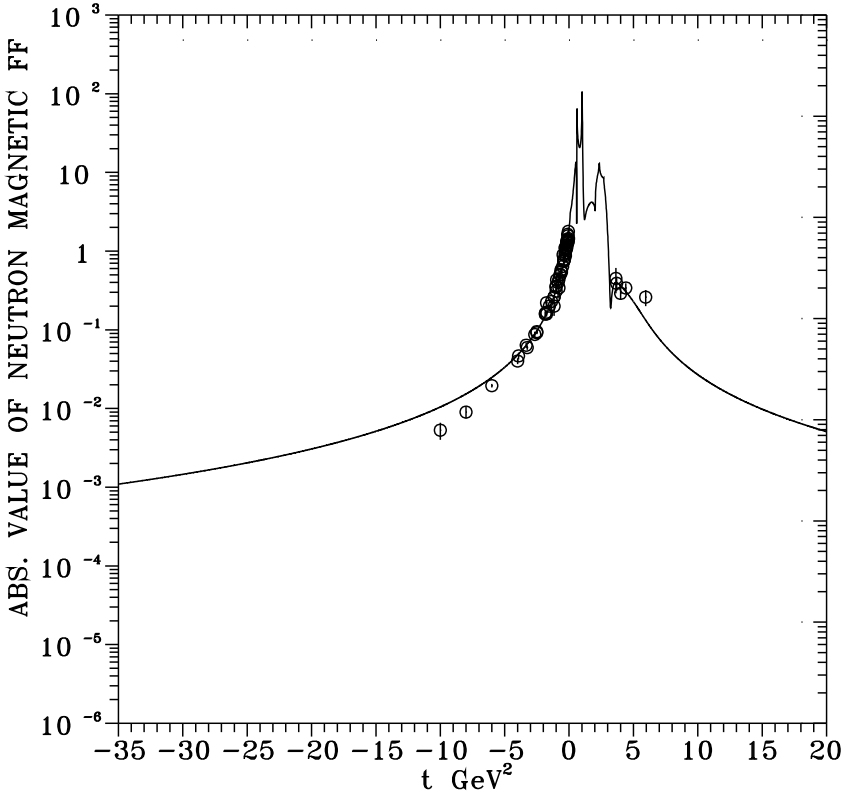
Prediction of **proton magnetic FF** behavior by *U&A* model respecting *SU*(3) symmetry and OZI rule violation

U&A MODEL OF NUCLEON EM STRUCTURE



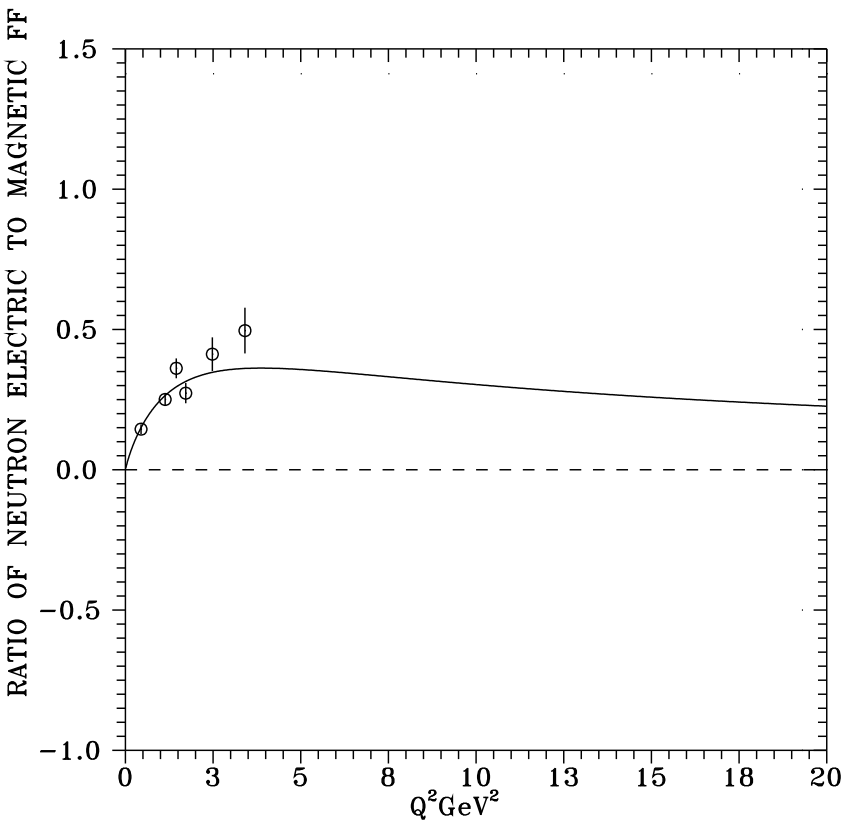
Prediction of **neutron electric FF** behavior by *U&A* model respecting *SU*(3) symmetry and OZI rule violation

U&A MODEL OF NUCLEON EM STRUCTURE



Prediction of **neutron magnetic FF** behavior by *U&A* model respecting *SU*(3) symmetry and OZI rule violation

U&A MODEL OF NUCLEON EM STRUCTURE



Prediction of **neutron electric to magnetic FFs ratio** behavior by *U&A* model respecting $SU(3)$ symmetry and OZI rule violation

U&A MODEL OF NUCLEON EM STRUCTURE

one determines **all free parameters of the model**

$$
\begin{aligned}
F_{1s}^{N} &: \quad (f^{(1)}_{\omega' NN}/f_{\omega'}), (f^{(1)}_{\phi' NN}/f_{\phi'}), (f^{(1)}_{\omega'' NN}/f_{\omega''}), (f^{(1)}_{\phi'' NN}/f_{\phi''}) \\
F_{1v}^{N} &: \quad (f^{(1)}_{\rho'' NN}/f_{\rho''}) \\
F_{2s}^{N} &: \quad (f^{(2)}_{\phi' NN}/f_{\phi'}), (f^{(2)}_{\omega'' NN}/f_{\omega''}), (f^{(2)}_{\phi'' NN}/f_{\phi''}) \\
F_{2v}^{N} &: \quad 0
\end{aligned}
$$

NOTE: One does not see here coupling constants ratios $(f^{(1)}_{\omega NN}/f_{\omega}), (f^{(1)}_{\phi NN}/f_{\phi})$, $(f^{(1)}_{\rho NN}/f_{\rho}), (f^{(1)}_{\rho' NN}/f_{\rho'})$, $(f^{(2)}_{\omega NN}/f_{\omega}), (f^{(2)}_{\phi NN}/f_{\phi})$, $(f^{(2)}_{\omega' NN}/f_{\omega'}), (f^{(2)}_{\rho NN}/f_{\rho})$, $(f^{(2)}_{\rho' NN}/f_{\rho'}), (f^{(2)}_{\rho'' NN}/f_{\rho''})$, which by demanding in constructed model correct norms and the asymptotic behaviors of FFs have been **expressed through special combinations of vector meson masses**.

HYPERONS EM STRUCTURE MODEL

Similarly to nucleons, one can construct also the **advanced** $U\&A$ **model of hyperon EM FFs** to be completely described by the Sachs electric $G_E^h(t)$ and magnetic $G_M^h(t)$ FFs.

$$F_{1s}^{\Lambda}[V(t)] = \left(\frac{1-V^2}{1-V_\Lambda^2}\right)^4 \left[L_\phi(V) L_{\omega'}(V) \frac{(C_\phi^{1s} - C_{\omega'}^{1s})}{(C_\phi^{1s} - C_\omega^{1s})} + L_\omega(V) L_{\omega'}(V) \frac{(C_\omega^{1s} - C_{\omega'}^{1s})}{(C_\omega^{1s} - C_\phi^{1s})} - \right.$$

$$\left. - L_\omega(V) L_\phi(V) \right] (f_{\omega'\Lambda\Lambda}^{(1)} / f_{\omega'}) +$$

$$+ \left(\frac{1-V^2}{1-V_\Lambda^2}\right)^4 \left[L_\phi(V) H_{\phi'}(V) \frac{(C_\phi^{1s} - C_{\phi'}^{1s})}{(C_\phi^{1s} - C_\omega^{1s})} + L_\omega(V) H_{\phi'}(V) \frac{(C_\omega^{1s} - C_{\phi'}^{1s})}{(C_\omega^{1s} - C_\phi^{1s})} - \right.$$

$$\left. - L_\omega(V) L_\phi(V) \right] (f_{\phi'\Lambda\Lambda}^{(1)} / f_{\phi'}) +$$

HYPERONS EM STRUCTURE MODEL

$$+\left(\frac{1-V^2}{1-V_\Lambda^2}\right)^4\left[L_\phi(V)H_{\omega''}(V)\frac{(C_\phi^{1s}-C_{\omega''}^{1s})}{(C_\phi^{1s}-C_\omega^{1s})}+L_\omega(V)H_{\omega''}(V)\frac{(C_\omega^{1s}-C_{\omega''}^{1s})}{(C_\omega^{1s}-C_\phi^{1s})}-\right.$$

$$\left.-L_\omega(V)L_\phi(V)\right](f^{(1)}_{\omega''\Lambda\Lambda}/f_{\omega''})+$$

$$+\left(\frac{1-V^2}{1-V_\Lambda^2}\right)^4\left[L_\phi(V)H_{\phi''}(V)\frac{(C_\phi^{1s}-C_{\phi''}^{1s})}{(C_\phi^{1s}-C_\omega^{1s})}+L_\omega(V)H_{\phi''}(V)\frac{(C_\omega^{1s}-C_{\phi''}^{1s})}{(C_\omega^{1s}-C_\phi^{1s})}-\right.$$

$$\left.-L_\omega(V)L_\phi(V)\right](f^{(1)}_{\phi''\Lambda\Lambda}/f_{\phi''})$$

HYPERONS EM STRUCTURE MODEL

$$F_{2s}^{\Lambda}[U(t)] = \left(\frac{1-U^2}{1-U_{\Lambda}^2}\right)^6 \mu_{\Lambda} L_{\omega}(U) L_{\phi}(U) L_{\omega'}(U) +$$

$$+\left(\frac{1-U^2}{1-U_N^2}\right)^6 \Bigg[L_{\phi}(U) L_{\omega'}(U) H_{\phi'}(U) \frac{(C_{\phi}^{2s} - C_{\phi'}^{2s})(C_{\omega'}^{2s} - C_{\phi'}^{2s})}{(C_{\phi}^{2s} - C_{\omega}^{2s})(C_{\omega'}^{2s} - C_{\omega}^{2s})} +$$

$$+ L_{\omega}(U) L_{\omega'}(U) H_{\phi'}(U) \frac{(C_{\omega}^{2s} - C_{\phi'}^{2s})(C_{\omega'}^{2s} - C_{\phi'}^{2s})}{(C_{\omega}^{2s} - C_{\phi}^{2s})(C_{\omega'}^{2s} - C_{\phi}^{2s})} +$$

$$+ L_{\omega}(U) L_{\phi}(U) H_{\phi'}(U) \frac{(C_{\omega}^{2s} - C_{\phi'}^{2s})(C_{\phi}^{2s} - C_{\phi'}^{2s})}{(C_{\omega}^{2s} - C_{\omega'}^{2s})(C_{\phi}^{2s} - C_{\omega'}^{2s})} -$$

$$- L_{\omega}(U) L_{\phi}(U) L_{\omega'}(U) \Bigg] (f_{\phi'\Lambda\Lambda}^{(2)} / f_{\phi'}) +$$

HYPERONS EM STRUCTURE MODEL

$$
\begin{aligned}
+\left(\frac{1-U^2}{1-U_\Lambda^2}\right)^6 \Bigg[& L_\phi(U)L_{\omega'}(U)H_{\omega''}(U)\frac{(C_\phi^{2s}-C_{\omega''}^{2s})(C_{\omega'}^{2s}-C_{\omega''}^{2s})}{(C_\phi^{2s}-C_\omega^{2s})(C_{\omega'}^{2s}-C_\omega^{2s})} + \\
& + L_\omega(U)L_{\omega'}(U)H_{\omega''}(U)\frac{(C_\omega^{2s}-C_{\omega''}^{2s})(C_{\omega'}^{2s}-C_{\omega''}^{2s})}{(C_\omega^{2s}-C_\phi^{2s})(C_{\omega'}^{2s}-C_\phi^{2s})} + \\
& + L_\omega(U)L_\phi(U)H_{\omega''}(U)\frac{(C_\omega^{2s}-C_{\omega''}^{2s})(C_\phi^{2s}-C_{\omega''}^{2s})}{(C_\omega^{2s}-C_{\omega'}^{2s})(C_\phi^{2s}-C_{\omega'}^{2s})} - \\
& - L_\omega(U)L_\phi(U)L_{\omega'}(U)\Bigg](f^{(2)}_{\omega''\Lambda\Lambda}/f_{\omega''}) +
\end{aligned}
$$

HYPERONS EM STRUCTURE MODEL

$$
\begin{aligned}
+\left(\frac{1-U^2}{1-U_\Lambda^2}\right)^6 \Bigg[& L_\phi(U)L_{\omega'}(U)H_{\phi''}(U)\frac{(C_\phi^{2s}-C_{\phi''}^{2s})(C_{\omega'}^{2s}-C_{\phi''}^{2s})}{(C_\phi^{2s}-C_\omega^{2s})(C_{\omega'}^{2s}-C_\omega^{2s})} + \\
& +L_\omega(U)L_{\omega'}(U)H_{\phi''}(U)\frac{(C_\omega^{2s}-C_{\phi''}^{2s})(C_{\omega'}^{2s}-C_{\phi''}^{2s})}{(C_\omega^{2s}-C_\phi^{2s})(C_{\omega'}^{2s}-C_\phi^{2s})} + \\
& +L_\omega(U)L_\phi(U)H_{\phi''}(U)\frac{(C_\omega^{2s}-C_{\phi''}^{2s})(C_\phi^{2s}-C_{\phi''}^{2s})}{(C_\omega^{2s}-C_{\omega'}^{2s})(C_\phi^{2s}-C_{\omega'}^{2s})} - \\
& -L_\omega(U)L_\phi(U)L_{\omega'}(U)\Bigg](f^{(2)}_{\phi''\Lambda\Lambda}/f_{\phi''})
\end{aligned}
$$

HYPERONS EM STRUCTURE MODEL

$$F_{1s}^{\Sigma}[V(t)] = \left(\frac{1-V^2}{1-V_\Sigma^2}\right)^4 \left[L_\phi(V) L_{\omega'}(V) \frac{(C_\phi^{1s} - C_{\omega'}^{1s})}{(C_\phi^{1s} - C_\omega^{1s})} + L_\omega(V) L_{\omega'}(V) \frac{(C_\omega^{1s} - C_{\omega'}^{1s})}{(C_\omega^{1s} - C_\phi^{1s})} - \right.$$

$$\left. - L_\omega(V) L_\phi(V) \right] (f^{(1)}_{\omega'\Sigma\Sigma}/f_{\omega'}) +$$

$$+ \left(\frac{1-V^2}{1-V_\Sigma^2}\right)^4 \left[L_\phi(V) H_{\phi'}(V) \frac{(C_\phi^{1s} - C_{\phi'}^{1s})}{(C_\phi^{1s} - C_\omega^{1s})} + L_\omega(V) H_{\phi'}(V) \frac{(C_\omega^{1s} - C_{\phi'}^{1s})}{(C_\omega^{1s} - C_\phi^{1s})} - \right.$$

$$\left. - L_\omega(V) L_\phi(V) \right] (f^{(1)}_{\phi'\Sigma\Sigma}/f_{\phi'}) +$$

HYPERONS EM STRUCTURE MODEL

$$+\left(\frac{1-V^2}{1-V_\Sigma^2}\right)^4\left[L_\phi(V)H_{\omega''}(V)\frac{(C_\phi^{1s}-C_{\omega''}^{1s})}{(C_\phi^{1s}-C_\omega^{1s})}+L_\omega(V)H_{\omega''}(V)\frac{(C_\omega^{1s}-C_{\omega''}^{1s})}{(C_\omega^{1s}-C_\phi^{1s})}-\right.$$

$$\left.-L_\omega(V)L_\phi(V)\right](f^{(1)}_{\omega''\Sigma\Sigma}/f_{\omega''})+$$

$$+\left(\frac{1-V^2}{1-V_\Sigma^2}\right)^4\left[L_\phi(V)H_{\phi''}(V)\frac{(C_\phi^{1s}-C_{\phi''}^{1s})}{(C_\phi^{1s}-C_\omega^{1s})}+L_\omega(V)H_{\phi''}(V)\frac{(C_\omega^{1s}-C_{\phi''}^{1s})}{(C_\omega^{1s}-C_\phi^{1s})}-\right.$$

$$\left.-L_\omega(V)L_\phi(V)\right](f^{(1)}_{\phi''\Sigma\Sigma}/f_{\phi''})$$

HYPERONS EM STRUCTURE MODEL

$$F_{1v}^{\Sigma}[W(t)] = \left(\frac{1-W^2}{1-W_{\Sigma}^2}\right)^4 \Bigg\{ L_{\rho}(W)L_{\rho'}(W) +$$

$$+\Bigg[L_{\rho'}(W)H_{\rho''}(W)\frac{(C_{\rho'}^{1v}-C_{\rho''}^{1v})}{(C_{\rho'}^{1v}-C_{\rho}^{1v})} + L_{\rho}(W)H_{\rho''}(W)\frac{(C_{\rho}^{1v}-C_{\rho''}^{1v})}{(C_{\rho}^{1v}-C_{\rho'}^{1v})} -$$

$$-L_{\rho}(W)L_{\rho'}(W)\Bigg](f_{\rho''\Sigma\Sigma}^{(1)}/f_{\rho''})\Bigg\}$$

HYPERONS EM STRUCTURE MODEL

$$F_{2s}^{\Sigma}[U(t)] = \left(\frac{1-U^2}{1-U_{\Sigma}^2}\right)^6 \frac{1}{2}(\mu_{\Sigma^+} + \mu_{\Sigma^-}) L_{\omega}(U) L_{\phi}(U) L_{\omega'}(U) +$$

$$+\left(\frac{1-U^2}{1-U_N^2}\right)^6 \Bigg[L_{\phi}(U) L_{\omega'}(U) H_{\phi'}(U) \frac{(C_{\phi}^{2s} - C_{\phi'}^{2s})(C_{\omega'}^{2s} - C_{\phi'}^{2s})}{(C_{\phi}^{2s} - C_{\omega}^{2s})(C_{\omega'}^{2s} - C_{\omega}^{2s})} +$$

$$+ L_{\omega}(U) L_{\omega'}(U) H_{\phi'}(U) \frac{(C_{\omega}^{2s} - C_{\phi'}^{2s})(C_{\omega'}^{2s} - C_{\phi'}^{2s})}{(C_{\omega}^{2s} - C_{\phi}^{2s})(C_{\omega'}^{2s} - C_{\phi}^{2s})} +$$

$$+ L_{\omega}(U) L_{\phi}(U) H_{\phi'}(U) \frac{(C_{\omega}^{2s} - C_{\phi'}^{2s})(C_{\phi}^{2s} - C_{\phi'}^{2s})}{(C_{\omega}^{2s} - C_{\omega'}^{2s})(C_{\phi}^{2s} - C_{\omega'}^{2s})} -$$

$$- L_{\omega}(U) L_{\phi}(U) L_{\omega'}(U) \Bigg] (f_{\phi'\Sigma\Sigma}^{(2)} / f_{\phi'}) +$$

HYPERONS EM STRUCTURE MODEL

$$
\begin{aligned}
+\left(\frac{1-U^2}{1-U_\Sigma^2}\right)^6 \Bigg[& L_\phi(U)L_{\omega'}(U)H_{\omega''}(U)\frac{(C_\phi^{2s}-C_{\omega''}^{2s})(C_{\omega'}^{2s}-C_{\omega''}^{2s})}{(C_\phi^{2s}-C_\omega^{2s})(C_{\omega'}^{2s}-C_\omega^{2s})} + \\
& + L_\omega(U)L_{\omega'}(U)H_{\omega''}(U)\frac{(C_\omega^{2s}-C_{\omega''}^{2s})(C_{\omega'}^{2s}-C_{\omega''}^{2s})}{(C_\omega^{2s}-C_\phi^{2s})(C_{\omega'}^{2s}-C_\phi^{2s})} + \\
& + L_\omega(U)L_\phi(U)H_{\omega''}(U)\frac{(C_\omega^{2s}-C_{\omega''}^{2s})(C_\phi^{2s}-C_{\omega''}^{2s})}{(C_\omega^{2s}-C_{\omega'}^{2s})(C_\phi^{2s}-C_{\omega'}^{2s})} - \\
& - L_\omega(U)L_\phi(U)L_{\omega'}(U)\Bigg](f^{(2)}_{\omega''\Sigma\Sigma}/f_{\omega''}) +
\end{aligned}
$$

HYPERONS EM STRUCTURE MODEL

$$
\begin{aligned}
+\left(\frac{1-U^2}{1-U_\Sigma^2}\right)^6 \Bigg[& L_\phi(U) L_{\omega'}(U) H_{\phi''}(U) \frac{(C_\phi^{2s} - C_{\phi''}^{2s})(C_{\omega'}^{2s} - C_{\phi''}^{2s})}{(C_\phi^{2s} - C_\omega^{2s})(C_{\omega'}^{2s} - C_\omega^{2s})} + \\
& + L_\omega(U) L_{\omega'}(U) H_{\phi''}(U) \frac{(C_\omega^{2s} - C_{\phi''}^{2s})(C_{\omega'}^{2s} - C_{\phi''}^{2s})}{(C_\omega^{2s} - C_\phi^{2s})(C_{\omega'}^{2s} - C_\phi^{2s})} + \\
& + L_\omega(U) L_\phi(U) H_{\phi''}(U) \frac{(C_\omega^{2s} - C_{\phi''}^{2s})(C_\phi^{2s} - C_{\phi''}^{2s})}{(C_\omega^{2s} - C_{\omega'}^{2s})(C_\phi^{2s} - C_{\omega'}^{2s})} - \\
& - L_\omega(U) L_\phi(U) L_{\omega'}(U) \Bigg] (f^{(2)}_{\phi''\Sigma\Sigma} / f_{\phi''})
\end{aligned}
$$

HYPERONS EM STRUCTURE MODEL

$$F_{2v}^{\Sigma}[X(t)] = \left(\frac{1-X^2}{1-X_{\Sigma}^2}\right)^6 \left\{\frac{1}{2}(\mu_{\Sigma^+} - \mu_{\Sigma^-} - 2)L_{\rho}(U)L_{\rho'}(U)H_{\rho''}(U)\right\}$$

HYPERONS EM STRUCTURE MODEL

$$F_{1s}^{\Xi}[V(t)] = -\left(\frac{1-V^2}{1-V_{\Xi}^2}\right)^4 \frac{1}{2} L_\omega(V) L_\phi(V) +$$

$$+\left(\frac{1-V^2}{1-V_{\Xi}^2}\right)^4 \left[L_\phi(V) L_{\omega'}(V) \frac{(C_\phi^{1s} - C_{\omega'}^{1s})}{(C_\phi^{1s} - C_\omega^{1s})} + L_\omega(V) L_{\omega'}(V) \frac{(C_\omega^{1s} - C_{\omega'}^{1s})}{(C_\omega^{1s} - C_\phi^{1s})} - \right.$$

$$\left. - L_\omega(V) L_\phi(V) \right] (f_{\omega' \Xi\Xi}^{(1)} / f_{\omega'}) +$$

$$+\left(\frac{1-V^2}{1-V_{\Xi}^2}\right)^4 \left[L_\phi(V) H_{\phi'}(V) \frac{(C_\phi^{1s} - C_{\phi'}^{1s})}{(C_\phi^{1s} - C_\omega^{1s})} + L_\omega(V) H_{\phi'}(V) \frac{(C_\omega^{1s} - C_{\phi'}^{1s})}{(C_\omega^{1s} - C_\phi^{1s})} - \right.$$

$$\left. - L_\omega(V) L_\phi(V) \right] (f_{\phi' \Xi\Xi}^{(1)} / f_{\phi'}) +$$

HYPERONS EM STRUCTURE MODEL

$$+\left(\frac{1-V^2}{1-V_{\Xi}^2}\right)^4\left[L_\phi(V)H_{\omega''}(V)\frac{(C_\phi^{1s}-C_{\omega''}^{1s})}{(C_\phi^{1s}-C_\omega^{1s})}+L_\omega(V)H_{\omega''}(V)\frac{(C_\omega^{1s}-C_{\omega''}^{1s})}{(C_\omega^{1s}-C_\phi^{1s})}-\right.$$

$$\left.-L_\omega(V)L_\phi(V)\right](f^{(1)}_{\omega''\Xi\Xi}/f_{\omega''})+$$

$$+\left(\frac{1-V^2}{1-V_{\Xi}^2}\right)^4\left[L_\phi(V)H_{\phi''}(V)\frac{(C_\phi^{1s}-C_{\phi''}^{1s})}{(C_\phi^{1s}-C_\omega^{1s})}+L_\omega(V)H_{\phi''}(V)\frac{(C_\omega^{1s}-C_{\phi''}^{1s})}{(C_\omega^{1s}-C_\phi^{1s})}-\right.$$

$$\left.-L_\omega(V)L_\phi(V)\right](f^{(1)}_{\phi''\Xi\Xi}/f_{\phi''})$$

HYPERONS EM STRUCTURE MODEL

$$F_{1v}^{\Xi}[W(t)] = \left(\frac{1-W^2}{1-W_{\Xi}^2}\right)^4 \left\{ \frac{1}{2} L_\rho(W) L_{\rho'}(W) + \right.$$

$$+ \left[L_{\rho'}(W) H_{\rho''}(W) \frac{(C_{\rho'}^{1v} - C_{\rho''}^{1v})}{(C_{\rho'}^{1v} - C_{\rho}^{1v})} + L_\rho(W) H_{\rho''}(W) \frac{(C_{\rho}^{1v} - C_{\rho''}^{1v})}{(C_{\rho}^{1v} - C_{\rho'}^{1v})} - \right.$$

$$\left. \left. - L_\rho(W) L_{\rho'}(W) \right] (f_{\rho''\Xi\Xi}^{(1)} / f_{\rho''}) \right\}$$

HYPERONS EM STRUCTURE MODEL

$$F_{2s}^{\Xi}[U(t)] = \left(\frac{1-U^2}{1-U_{\Xi}^2}\right)^6 \frac{1}{2}(\mu_{\Xi^0} + \mu_{\Xi^-} + 1) L_\omega(U) L_\phi(U) L_{\omega'}(U) +$$

$$+ \left(\frac{1-U^2}{1-U_N^2}\right)^6 \Bigg[L_\phi(U) L_{\omega'}(U) H_{\phi'}(U) \frac{(C_\phi^{2s} - C_{\phi'}^{2s})(C_{\omega'}^{2s} - C_{\phi'}^{2s})}{(C_\phi^{2s} - C_\omega^{2s})(C_{\omega'}^{2s} - C_\omega^{2s})} +$$

$$+ L_\omega(U) L_{\omega'}(U) H_{\phi'}(U) \frac{(C_\omega^{2s} - C_{\phi'}^{2s})(C_{\omega'}^{2s} - C_{\phi'}^{2s})}{(C_\omega^{2s} - C_\phi^{2s})(C_{\omega'}^{2s} - C_\phi^{2s})} +$$

$$+ L_\omega(U) L_\phi(U) H_{\phi'}(U) \frac{(C_\omega^{2s} - C_{\phi'}^{2s})(C_\phi^{2s} - C_{\phi'}^{2s})}{(C_\omega^{2s} - C_{\omega'}^{2s})(C_\phi^{2s} - C_{\omega'}^{2s})} -$$

$$- L_\omega(U) L_\phi(U) L_{\omega'}(U) \Bigg] (f_{\phi'\Xi\Xi}^{(2)} / f_{\phi'}) +$$

HYPERONS EM STRUCTURE MODEL

$$+\left(\frac{1-U^2}{1-U_{\Xi}^2}\right)^6\Bigg[L_\phi(U)L_{\omega'}(U)H_{\omega''}(U)\frac{(C_\phi^{2s}-C_{\omega''}^{2s})(C_{\omega'}^{2s}-C_{\omega''}^{2s})}{(C_\phi^{2s}-C_\omega^{2s})(C_{\omega'}^{2s}-C_\omega^{2s})}+$$

$$+L_\omega(U)L_{\omega'}(U)H_{\omega''}(U)\frac{(C_\omega^{2s}-C_{\omega''}^{2s})(C_{\omega'}^{2s}-C_{\omega''}^{2s})}{(C_\omega^{2s}-C_\phi^{2s})(C_{\omega'}^{2s}-C_\phi^{2s})}+$$

$$+L_\omega(U)L_\phi(U)H_{\omega''}(U)\frac{(C_\omega^{2s}-C_{\omega''}^{2s})(C_\phi^{2s}-C_{\omega''}^{2s})}{(C_\omega^{2s}-C_{\omega'}^{2s})(C_\phi^{2s}-C_{\omega'}^{2s})}-$$

$$-L_\omega(U)L_\phi(U)L_{\omega'}(U)\Bigg](f^{(2)}_{\omega''\Xi\Xi}/f_{\omega''})+$$

HYPERONS EM STRUCTURE MODEL

$$
\begin{aligned}
+\left(\frac{1-U^2}{1-U_{\Xi}^2}\right)^6 \Bigg[& L_\phi(U) L_{\omega'}(U) H_{\phi''}(U) \frac{(C_\phi^{2s} - C_{\phi''}^{2s})(C_{\omega'}^{2s} - C_{\phi''}^{2s})}{(C_\phi^{2s} - C_\omega^{2s})(C_{\omega'}^{2s} - C_\omega^{2s})} + \\
& + L_\omega(U) L_{\omega'}(U) H_{\phi''}(U) \frac{(C_\omega^{2s} - C_{\phi''}^{2s})(C_{\omega'}^{2s} - C_{\phi''}^{2s})}{(C_\omega^{2s} - C_\phi^{2s})(C_{\omega'}^{2s} - C_\phi^{2s})} + \\
& + L_\omega(U) L_\phi(U) H_{\phi''}(U) \frac{(C_\omega^{2s} - C_{\phi''}^{2s})(C_\phi^{2s} - C_{\phi''}^{2s})}{(C_\omega^{2s} - C_{\omega'}^{2s})(C_\phi^{2s} - C_{\omega'}^{2s})} - \\
& - L_\omega(U) L_\phi(U) L_{\omega'}(U) \Bigg] (f^{(2)}_{\phi''\Xi\Xi} / f_{\phi''})
\end{aligned}
$$

HYPERONS EM STRUCTURE MODEL

$$F_{2v}^{\Xi}[X(t)] = \left(\frac{1-X^2}{1-X_{\Xi}^2}\right)^6 \left\{\frac{1}{2}(\mu_{\Xi^0} - \mu_{\Xi^-} - 1)L_\rho(U)L_{\rho'}(U)H_{\rho''}(U)\right\}$$

HYPERONS EM STRUCTURE MODEL

But this hyperon EM structure model contains the **vector-meson-hyperon coupling constant ratios**

$$
\begin{aligned}
F_{1s}^h &: (f^{(1)}_{\omega' hh}/f_{\omega'}), (f^{(1)}_{\phi' hh}/f_{\phi'}), (f^{(1)}_{\omega'' hh}/f_{\omega''}), (f^{(1)}_{\phi'' hh}/f_{\phi''}) \\
F_{1v}^h &: (f^{(1)}_{\rho'' hh}/f_{\rho''}) \\
F_{2s}^h &: (f^{(2)}_{\phi' hh}/f_{\phi'}), (f^{(2)}_{\omega'' hh}/f_{\omega''}), (f^{(2)}_{\phi'' hh}/f_{\phi''}) \\
F_{2v}^h &: 0
\end{aligned}
$$

as **free parameters**. Again coupling constants $(f^{(1)}_{\omega hh}/f_{\omega}), (f^{(1)}_{\phi hh}/f_{\phi})$, $(f^{(1)}_{\rho hh}/f_{\rho}), (f^{(1)}_{\rho' hh}/f_{\rho'})$, $(f^{(2)}_{\omega hh}/f_{\omega}), (f^{(2)}_{\phi hh}/f_{\phi})$, $(f^{(2)}_{\omega' hh}/f_{\omega'}), (f^{(2)}_{\rho hh}/f_{\rho})$, $(f^{(2)}_{\rho' hh}/f_{\rho'}), (f^{(2)}_{\rho'' hh}/f_{\rho''})$, are absent among these free parameters, because they have been **expressed through vector meson masses**.

HYPERONS EM STRUCTURE MODEL

These free parameters, in principle, **could be determined by a comparison of the model with some data on the hyperon EM FFs,** like in the case of nucleons.

However, **there are no such data**, except two experiments with elastic scattering of Σ^- hyperons on atomic electrons for very small momentum transfer squared values in the space-like region **giving just the value of the corresponding charge mean square radius of the Σ^- hyperon** and few experimental points **on the total cross section of electron-positron annihilation into HYPERON-ANTIHYPERON pairs**.

HYPERONS EM STRUCTURE MODEL

Nevertheless also **in such case one finds the solution**.

Unknown parameters of the hyperon EM structure model can be predicted theoretically:

- by using $SU(3)$ invariant vector-meson-baryon Lagrangian
- results from the analysis of nucleons
- provided that the **universal vector-meson coupling constants f_V in all considered coupling constants ratios are known numerically**.

HYPERONS EM STRUCTURE MODEL

The $SU(3)$ **invariant Lagrangian** of vector meson-baryon interactions

$$Tr(L_{VB\bar{B}}) = \frac{i}{\sqrt{2}} f^F [\bar{B}^\alpha_\beta \gamma_\mu B^\beta_\gamma - \bar{B}^\beta_\gamma \gamma_\mu B^\alpha_\beta](V_\mu)^\gamma_\alpha + \frac{i}{\sqrt{2}} f^D [\bar{B}^\beta_\gamma \gamma_\mu B^\alpha_\beta + \bar{B}^\alpha_\gamma \gamma_\mu B^\beta_\gamma](V_\mu)^\gamma_\alpha + \frac{i}{\sqrt{2}} f^S \bar{B}^\alpha_\beta \gamma_\mu B^\beta_\alpha \omega^0_\mu$$

provides the relations

HYPERONS EM STRUCTURE MODEL

$$
\begin{aligned}
f^{1,2}_{\rho NN} &= \frac{1}{2}(f^D_{1,2} + f^F_{1,2}) \\
f^{1,2}_{\omega NN} &= \frac{1}{\sqrt{2}} cos\theta f^S_{1,2} - \frac{1}{2\sqrt{3}} sin\theta (3 f^F_{1,2} - f^D_{1,2}) \\
f^{1,2}_{\phi NN} &= \frac{1}{\sqrt{2}} sin\theta f^S_{1,2} + \frac{1}{2\sqrt{3}} cos\theta (3 f^F_{1,2} - f^D_{1,2})
\end{aligned}
$$

where the **left hand side is known**, if we take **numerical values of the nucleon coupling constant ratios** from nucleon EM FF data analysis and the **universal vector meson coupling constants** f_ρ, f_ω, f_ϕ **from data on** $\Gamma(V \to e^+e^-)$ to be determined by the relation $\Gamma(V \to e^+e^-) = \frac{\alpha^2 m_V}{3}(\frac{f_V^2}{4\pi})^{-1}$.

HYPERONS EM STRUCTURE MODEL

The solution of the last system of algebraic equations according to $f^D_{1,2}$, $f^F_{1,2}$, $f^S_{1,2}$ with numerical values of $f^{1,2}_{\rho NN}$, $f^{1,2}_{\omega NN}$ and $f^{1,2}_{\phi NN}$, **enables to predict all following vector-meson-hyperon coupling constants**

HYPERONS EM STRUCTURE MODEL

$$
\begin{aligned}
f^{1,2}_{\omega\Lambda\Lambda} &= \frac{1}{\sqrt{2}} cos\theta f^S_{1,2} + \frac{1}{\sqrt{3}} sin\theta f^D_{1,2} \\
f^{1,2}_{\phi\Lambda\Lambda} &= \frac{1}{\sqrt{2}} sin\theta f^S_{1,2} - \frac{1}{\sqrt{3}} cos\theta f^D_{1,2} \\
f^{1,2}_{\rho\Sigma\Sigma} &= -f^F_{1,2} \\
f^{1,2}_{\omega\Sigma\Sigma} &= \frac{1}{\sqrt{2}} cos\theta f^S_{1,2} - \frac{1}{\sqrt{3}} sin\theta f^D_{1,2} \\
f^{1,2}_{\phi\Sigma\Sigma} &= \frac{1}{\sqrt{2}} sin\theta f^S_{1,2} + \frac{1}{\sqrt{3}} cos\theta f^D_{1,2} \\
f^{1,2}_{\rho\Xi\Xi} &= \frac{1}{2}(f^D_{1,2} - f^F_{1,2}) \\
f^{1,2}_{\omega\Xi\Xi} &= \frac{1}{\sqrt{2}} cos\theta f^S_{1,2} + \frac{1}{2\sqrt{3}} sin\theta (3f^F_{1,2} + f^D_{1,2}) \\
f^{1,2}_{\phi\Xi\Xi} &= \frac{1}{\sqrt{2}} sin\theta f^S_{1,2} - \frac{1}{2\sqrt{3}} cos\theta (3f^F_{1,2} + f^D_{1,2})
\end{aligned}
$$

HYPERONS EM STRUCTURE MODEL

where $\theta = 39.83^o$ is the **mixing angle** to be determined by the **Gell-Mann-Okubo quadratic mass formula**

$$m_\phi^2 cos^2\theta + m_\omega^2 sin^2\theta = \frac{4m_{K^*}^2 - m_\rho^2}{3}.$$

HYPERONS EM STRUCTURE MODEL

Finally, dividing the determined vector-meson-hyperon coupling constants by the corresponding universal vector-meson coupling constants f_ρ, f_ω, f_ϕ, **one finds searched vector-meson-hyperon coupling constant ratios.**

Similarly one can proceed in a **determination of the first excited and the second excited vector-meson-hyperon coupling constants ratios**.

Here **big problem appeared**. There are no data on $\Gamma(V \to e^+e^-)$ for $\omega'(1420), \rho'(1450)), \phi'(1680)$ and $\omega''(1650), \rho''(1700), \phi''(2170)$, in order to determine f'_ρ, f'_ω, f'_ϕ and f''_ρ, f''_ω, f''_ϕ.

HYPERONS EM STRUCTURE MODEL

In order to avoid this problem to some extent, we have constructed the $U\&A$ model with explicit coupling constants ratios $(f^{(1,2)}_{\omega hh}/f_\omega), (f^{(1,2)}_{\phi hh}/f_\phi), (f^{(1)}_{\rho hh}/f_\rho)$, where we know numerical values of f_ρ, f_ω, f_ϕ and $(f^{(1,2)}_{\omega' hh}/f_{\omega'}), (f^{(1,2)}_{\phi' hh}/f_{\phi'})$, where one can find f'_ω, f'_ϕ by exploiting some model considerations.

The results are in progress.

As a first approximation, we have calculated at least $1/2^+$ octet baryon mean square charge radii in the framework of the **hyperon EM structure** $U\&A$ **model** to be compared with χPT predictions and existing experimental determinations (see Table).

HYPERONS EM STRUCTURE MODEL

baryon	$U\&A$ **model**	χ**PT**	**Exp.**
p	0.727	0.717	0.769
n	-.205	-.113	-.116
Λ	-.068	-.112	
Σ^+	1.090	0.602	
Σ^0	-.093	-.031	
Σ^-	0.536	0.673	0.915
Ξ^0	-.221	0.133	
Ξ^-	0.876	0.495	

Conclusions

- **All existing data** on the proton and neutron electric and magnetic FFs, $G_E^p(t)$, $G_M^p(t)$ and $G_E^n(t)$, $G_M^n(t)$, **have been reviewed.**
- The advanced $U\&A$ **nucleon EM structure model**, which successfully describes all today's experimental data in space-like and time-like regions simultaneously, **was elaborated.**
- The **results of the** $U\&A$ **nucleon EM structure model with a combination of** $SU(3)$ **symmetry** have been used for a construction of the $U\&A$ **EM structure model of the** $1/2^+$ **octet hyperons**.
- By means of the latter the **charge mean square radii of** $1/2^+$ **octet hyperons** have been calculated and compared with χPT predictions.

Thank you