PROCEEDINGS OF SCIENCE

Theoretical prediction of Λ, Σ, Ξ hyperon magnetic form factors $|G_M^Y(t)|$ behaviors and also of ratios $|G_E^Y(t)|/|G_M^Y(t)|$ in time-like region.

Stanislav Dubnička[*]
Institute of Physics, Slovak Academy of Sciences, Dúbravská cesta 9, 845 11 Bratislava, Slovakia
E-mail: stanislav.dubnicka@savba.sk

Anna-Zuzana Dubničková
Faculty of Mathematics, Physics and Informatics, Comenius University, Mlynská dolina, 842 48 Bratislava, Slovakia
E-mail: dubnickova@fmph.uniba.sk

Cyril Adamuščín
Institute of Physics, Slovak Academy of Sciences, Dúbravská cesta 9, 845 11 Bratislava, Slovakia
E-mail: cyril.adamuscin@savba.sk

Erik Bartoš
Institute of Physics, Slovak Academy of Sciences, Dúbravská cesta 9, 845 11 Bratislava, Slovakia
E-mail: erik.bartos@savba.sk

The advanced *Unitary&Analytic* hyperon EM structure model has been constructed and behaviors of the $|G_M^Y(t)|$ and the ratio $||G_E^Y(t)|/|G_M^Y(t)|$ are predicted in time-like region as functions of the total energy squared $t = W^2$ in the c.m. system of $Y\bar{Y}$, which are expected to be determined in measurements of the hyperon polar angle θ_Y in the $e^+e^- \to Y\bar{Y}$ processes.

The European Physical Society Conference on High Energy Physics
5-12 July
Venice, Italy

[*]Speaker.

PoS(EPS-HEP2017)757

Predicted behaviors of $|G_M^Y(t)|$ and $|G_E^Y(t)|/|G_M^Y(t)|$ in time-like region are valuable for experimentalists as they are already measured for Λ-hyperon [1] and are expected to be revealed in measurements of the Σ and Xi hyperon polar angle distributions $F(\cos\theta_Y) = N_{norm}[1+\cos^2\theta_Y + \frac{4m_Y^2}{t}(R^Y)^2(1-\cos^2\theta_Y)]$ in the $e^+e^- \to Y\bar{Y}$ processes, where $R^Y = |G_E^Y(t)|/|G_M^Y(t)|$ and $N_{norm} = f(|G_M^Y(t)|^2)$, $Y = \Sigma, \Xi$.

They all can be foretold by the *Unitary&Analytic* (U&A) nucleon electromagnetic (EM) structure model [2] formulated in the language of the iso-scalar and iso-vector parts of the Dirac and Pauli form factors (FFs) F_{1s}^Y, F_{1v}^Y and F_{2s}^Y, F_{2v}^Y, respectively, provided that the f^F, f^D, f^S coupling constants values in the SU(3) invariant Lagrangian of the vector-meson nonet V interaction with $1/2^+$ baryon octet B

$$L_{VB\bar{B}} = \frac{i}{\sqrt{2}}\{f^F[\bar{B}_\beta^\alpha\gamma_\mu B_\gamma^\beta - \bar{B}_\gamma^\beta\gamma_\mu B_\beta^\alpha](V^\mu)_\alpha^\gamma + f^D[\bar{B}_\beta^\alpha\gamma_\mu B_\gamma^\beta + \bar{B}_\gamma^\beta\gamma_\mu B_\beta^\alpha](V^\mu)_\alpha^\gamma + f^S\bar{B}_\beta^\alpha\gamma_\mu B_\alpha^\beta\omega_0^\mu\} \quad (1)$$

are known numerically [2, 3] and the signs of the universal vector-meson coupling constants f_ρ, f_ω, f_ϕ are specified [3], to be, however, dependent on the choice of the $\omega-\phi$ mixing configuration.

The main idea consists in the fact that the U&A nucleon EM structure model is valid also for $1/2^+$ octet hyperons. Only the coupling constant ratios in $F_{1s}^Y, F_{1v}^Y, F_{2s}^Y, F_{2v}^Y$ are different and they have to be, somehow, determined.

Really, the relations between the EM FFs of octet baryons and $F_{1s}^Y, F_{1v}^Y, F_{2s}^Y, F_{2v}^Y$ are

$$G_E^{p,n}(t) = [F_{1s}^N(t) \pm F_{1v}^N(t)] + \frac{t}{4m_N^2}[F_{2s}^N(t) \pm F_{2v}^N(t)]; \quad G_M^{p,n}(t) = [F_{1s}^N(t) \pm F_{1v}^N(t)] + [F_{2s}^N(t) \pm F_{2v}^N(t)]$$

$$G_E^\Lambda(t) = F_{1s}^\Lambda(t) + \frac{t}{4m_\Lambda^2}F_{2s}^\Lambda(t); \quad G_M^\Lambda(t) = F_{1s}^\Lambda(t) + F_{2s}^\Lambda(t)$$

$$G_E^{\Sigma^0}(t) = F_{1s}^\Sigma(t) + \frac{t}{4m_{\Sigma^0}^2}F_{2s}^\Sigma(t); \quad G_M^{\Sigma^0}(t) = F_{1s}^\Sigma(t) + F_{2s}^\Sigma(t)$$

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

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

where $F_{1s}^Y, F_{1v}^Y, F_{2s}^Y, F_{2v}^Y$ are defined on four sheeted Riemann surface in t-variable, containing some number of well confirmed vector meson resonances, also an effective inelastic threshold and depend on some coupling constants ratios to be free parameters of the model [2], whereby the latter are different for different member of the $1/2^+$ octet baryons as follows

$$F_{1s}^N = f[t_{in}^{1s}, (f_{\omega' NN}^1/f_{\omega'}), (f_{\phi' NN}^1/f_{\phi'}), (f_{\omega NN}^1/f_\omega), (f_{\phi NN}^1/f_\phi)]; \quad F_{1v}^N = f[t_{in}^{1v}, (f_{\rho NN}^1/f_\rho)]$$
$$F_{2s}^N = f[t_{in}^{2s}, (f_{\phi' NN}^2/f_{\phi'}), (f_{\omega NN}^2/f_\omega), (f_{\phi NN}^2/f_\phi)]; \quad F_{2v}^N = f[t_{in}^{2v}]$$

PoS(EPS-HEP2017)757

$$
\begin{aligned}
&F_{1s}^{\Lambda} = f[t_{in}^{1s}, (f^1_{\omega'\Lambda\Lambda}/f_{\omega'}), (f^1_{\phi'\Lambda\Lambda}/f_{\phi'}), (f^1_{\omega\Lambda\Lambda}/f_{\omega}), (f^1_{\phi\Lambda\Lambda}/f_{\phi})];\\
&F_{2s}^{\Lambda} = f[t_{in}^{2s}, (f^2_{\phi'\Lambda\Lambda}/f_{\phi'}), (f^2_{\omega\Lambda\Lambda}/f_{\omega}), (f^2_{\phi\Lambda\Lambda}/f_{\phi})]\\
&F_{1s}^{\Sigma} = f[t_{in}^{1s}, (f^1_{\omega'\Sigma\Sigma}/f_{\omega'}), (f^1_{\phi'\Sigma\Sigma}/f_{\phi'}), (f^1_{\omega\Sigma\Sigma}/f_{\omega}), (f^1_{\phi\Sigma\Sigma}/f_{\phi})] \quad F_{1v}^{\Sigma} = f[t_{in}^{1v}, (f^1_{\rho\Sigma\Sigma}/f_{\rho})]\\
&F_{2s}^{\Sigma} = f[t_{in}^{2s}, (f^2_{\phi'\Sigma\Sigma}/f_{\phi'}), (f^2_{\omega\Sigma\Sigma}/f_{\omega}), (f^2_{\phi\Sigma\Sigma}/f_{\phi})]; \quad F_{2v}^{\Sigma} = f[t_{in}^{2v}]\\
&F_{1s}^{\Xi} = f[t_{in}^{1s}, (f^1_{\omega'\Xi\Xi}/f_{\omega'}), (f^1_{\phi'\Xi\Xi}/f_{\phi'}), (f^1_{\omega\Xi\Xi}/f_{\omega}), (f^1_{\phi\Xi\Xi}/f_{\phi})]; \quad F_{1v}^{\Xi} = f[t_{in}^{1v}, (f^1_{\rho\Xi\Xi}/f_{\rho})]\\
&F_{2s}^{\Xi} = f[t_{in}^{2s}, (f^2_{\phi'\Xi\Xi}/f_{\phi'}), (f^2_{\omega\Xi\Xi}/f_{\omega}), (f^2_{\phi\Xi\Xi}/f_{\phi})]; \quad F_{2v}^{\Xi} = f[t_{in}^{2v}]
\end{aligned}
$$

While unknown parameters in the U&A model of the nucleon EM structure are determined in a fitting procedure of all existing data on the proton and neutron EM FFs in time-like and space-like regions simultaneously, the unknown parameters in the U&A hyperon EM structure models are determined from the previous ones by exploiting the Lagrangian (1).

However, before finding the unknown parameters of the U&A models of EM structure of hyperons, first the coupling constants f^F, f^D, f^S have to be determined.

- From the Lagrangian (1), by substituting an $\omega - \phi$ mixing configuration, one obtains the coupling constants of ρ, ω, ϕ vector-meson interactions with nucleons as functions of f^F, f^D, f^S and the $\omega - \phi$ mixing angle which is determined from the Gell-Mann-Okubo vector-meson quadratic mass formula.

- By a solution of such equations one obtains reversed relations, i.e. f^F, f^D, f^S as functions of the coupling constants of ρ, ω, ϕ vector-meson interactions with nucleons.

- Calculating the universal vector-meson coupling constants f_ρ, f_ω, f_ϕ from the experimental data on vector meson lepton widths, the coupling constants of ρ, ω, ϕ vector-meson interactions with nucleons are calculated from the determined in a fitting procedure of all existing data on the proton and neutron EM FFs coupling constants ratios $(f_{\rho NN}/f_\rho)$, $(f_{\omega NN}/f_\omega)$, $(f_{\phi NN}/f_\phi)$ and in a such way the f^F, f^D, f^S coupling constants values in the SU(3) invariant Lagrangian (1) of the vector-meson nonet V interaction with $1/2^+$ baryon octet B are determined.

- The predicted behaviors of $|G_M^Y(t)|$ and $|G_E^Y(t)|/|G_M^Y(t)|$ in time-like region are presented in Figs.1-6.

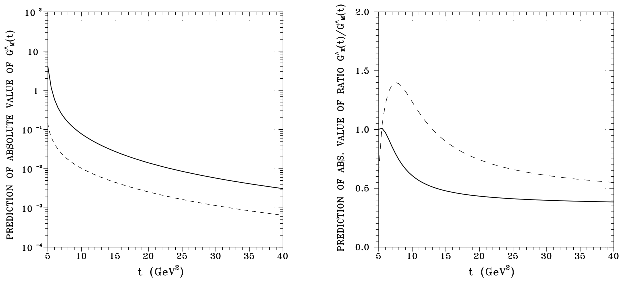

Fig.1: Predicted behavior of the Λ magnetic FF and ratio of its EM FFs in $t > 0$ region. Dashed lines are predictions for the proton.

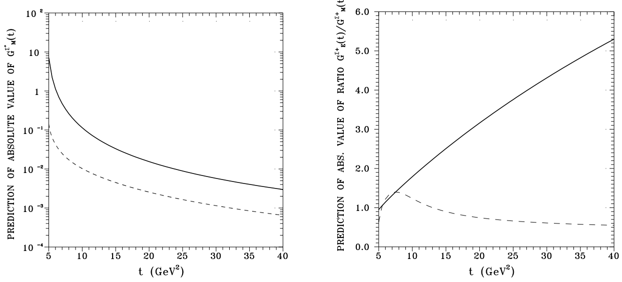

Fig.2: Predicted behavior of the Σ^+ magnetic FF and ratio of its EM FFs in $t > 0$ region. Dashed lines are predictions for the proton.

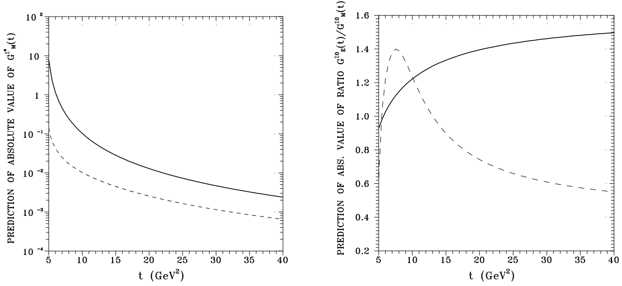

Fig.3: Predicted behavior of the Σ^0 magnetic FF and ratio of its EM FFs in $t > 0$ region. Dashed lines are predictions for the proton.

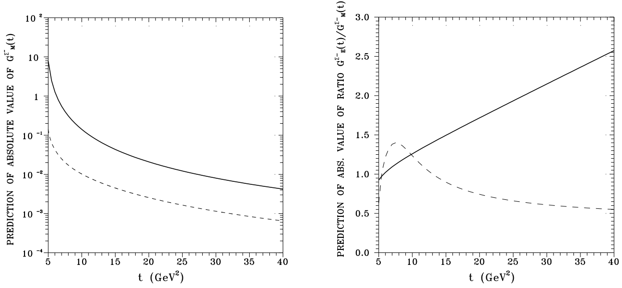

Fig.4: Predicted behavior of the Σ^- magnetic FF and ratio of its EM FFs in $t > 0$ region. Dashed lines are predictions for the proton.

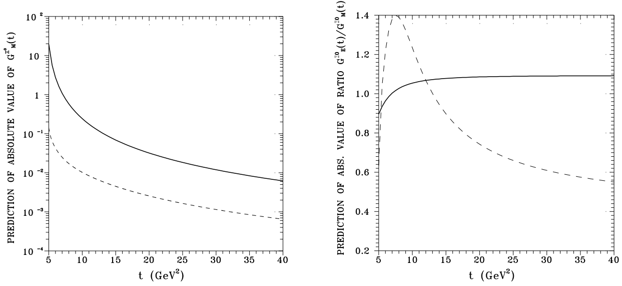

Fig.5: Predicted behavior of the Ξ^0 magnetic FF and ratio of its EM FFs in $t > 0$ region. Dashed lines are predictions for the proton.

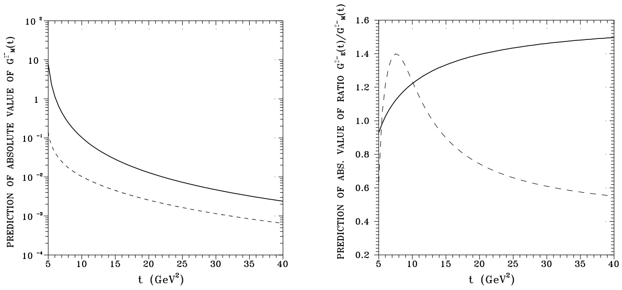

Fig.6: Predicted behavior of the Ξ^- magnetic FF and ratio of its EM FFs in $t > 0$ region. Dashed lines are predictions for the proton.

Some improvements in these predictions can be achieved, if:

– description of lepton widths for the first and the second excited states of the ρ, ω, ϕ mesons will be measured experimentally

– spectrum of excited meson masses contained in the Gell-Mann-Okubo quadratic mass formula are measured with higher precision, (this is connected with a better determination of the corresponding mixing angle value)

– more points of reliable values on the total cross-sections of the $e^+e^- \to Y\bar{Y}$ processes in different energies are measured (this will allow to determine precise values of the effective inelastic thresholds in the isoscalar and isovector parts of the corresponding Dirac and Pauli FFs.)

References

[1] B. Aubert et al.,(BaBar Collab.), *Phys. Rev.* **D76**, 092006 (2007).

[2] C. Adamuscin, E. Bartos, S. Dubnicka and A. Z. Dubnickova, Phys. Rev. C **93**, no. 5, 055208 (2016)

[3] Erratum in arXiv: 1706.05657 v1 [hep-ph] 18 Jun 2017.