Quark model calculations of baryon electromagnetic form factors in the large timelike q^2 region

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In collaboration with
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September 8, 2026

[1] **In transit**

Plan of the talk – Elastic Form Factors

Baryon timelike electromagnetic form factors at large q^2

Octet Baryon ($J^P = \frac{1}{2}^+$) : $J^\mu = F_1 \gamma^\mu + F_2 \frac{i\sigma^{\mu\nu} q_\nu}{2M}$ [Dirac/Pauli FF]

Electric and Magnetic FF (Sachs): $G_E = F_1 - \frac{Q^2}{4M^2} F_2$, $G_M = F_1 + F_2$

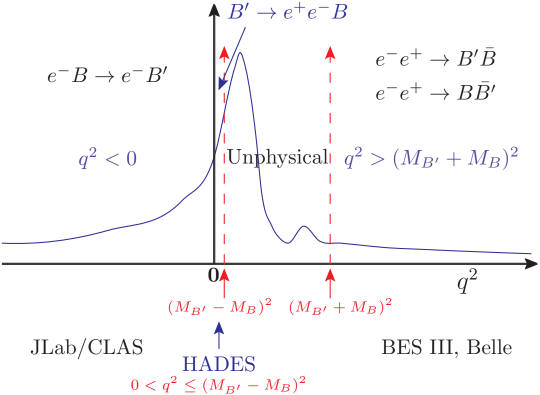
$q =$ transfer momentum, $Q^2 = -q^2$

- **Background**
- **Quark model calculations** for the spacelike region ($q^2 \leq 0$)
- **Extension to the timelike region** ($q^2 > 0$) – Effective FF and ratio $|G_E/G_M|$

G. Ramalho, M.P. Peña and K. Tsushima, PRD 101, 014014 (2020)
G. Ramalho, PRD 103, 074018 (2021)

G. Ramalho, M.P. Peña, K. Tsushima and M. K. Cheoun, PLB 858, 139060 (2024)

Background: baryon electromagnetic structure in $\neq$ regions



SL: $(Q^2 = -q^2 \geq 0)$: electron (baryon) scattering; N, N^* FF; $(\gamma^* N \to N^*)$: JLab, ...
TL: (large q^2): e^+e^-, $p\bar{p}$ scattering; B FF and $B'\bar{B}$ FF: BESIII, Belle
TL: (below pseudothreshold): $\pi B \to B^* \to \gamma^* B \to e^+e^- B$; Dalitz decay; HADES, ...

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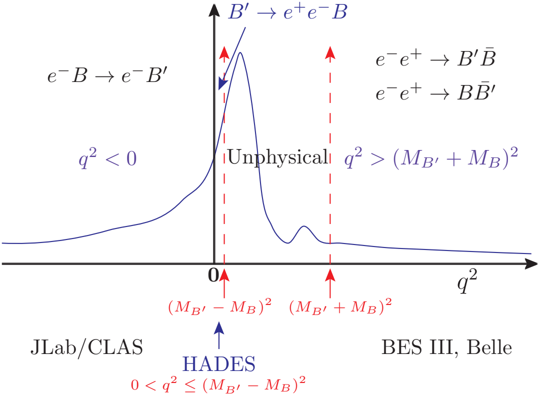

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Model calculations available for the three regimes

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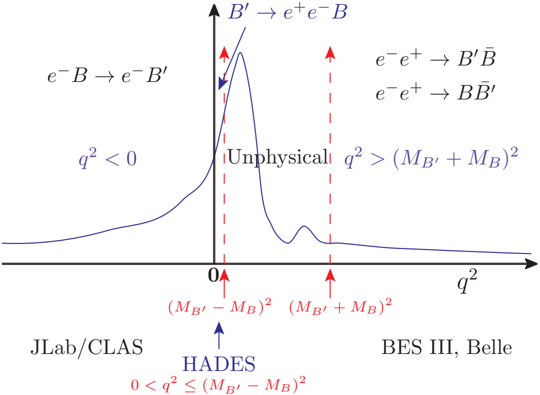

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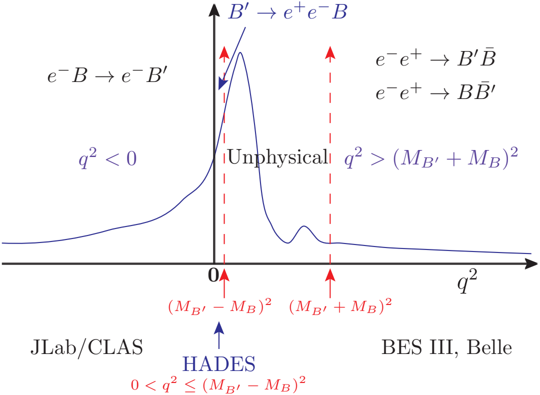
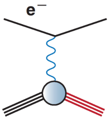
Model calculations available for the three regimes – Focus on TL/large-q^2

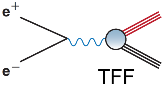
Background: baryon electromagnetic structure in $\neq$ regions





Spacelike $(q^2 \leq 0)$

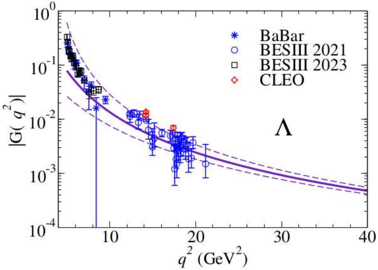
- Real FF
- Probe structure N^*
  $G_{N \to N^*}(Q^2)$

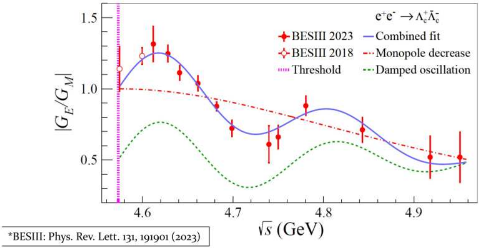


Timelike $(q^2 \geq 4M^2)$

- Complex FF
- Probe structure B (hyp.)
  $G_E(q^2)$, $G_M(q^2)$

Status of measurements in the timelike region





Integrated cross section: BaBar, CLEO, BESIII, $\tau = \frac{q^2}{4M^2}$
Effective FF: $|G|^2 \propto \left[|G_M|^2 + \frac{1}{2\tau}|G_E|^2\right]$

Differential cross section: $|G_E|$, $|G_M|$, $|G_E/G_M|$, BESIII

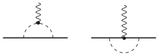
Spin polarization (complete measurements): $\Delta\Phi$ (relative phase), BESIII

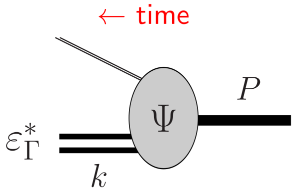
Covariant Spectator Quark Model (CSQM)

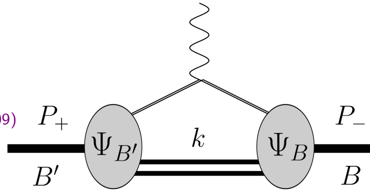
- **Covariant Spectator Theory: Baryons** $\equiv (qqq)$
  (1 off-shell $\oplus$ 2 spectator on-shell) Stadler, Gross and Frank, PRC 56, 2396 (1998); Gross and Agbakpe, PRC 73, 015203 (2006)
- Reduction of system to quark-diquark configuration
  diquark on-shell
  Wave functions: $SU_{SF}(6) \otimes O(3)$ symmetries
  Radial w.f. ψ_B **determined phenomenologically**
  (momemtum range parameters: β_1, β_2, β_3, ...)
  Gross, GR and Peña PRC 77, 015202 (2008); PRD 85, 093005 (2012)
- Electromagnetic interaction; relativistic impulse approximation **diquark on-shell**

$$J^\mu = 3 \sum_\Gamma \int_k \overline{\Psi}_{B'}(P_+, k) j_q^\mu \Psi_B(P_-, k)$$

- Constituent quark current $j_q^\mu(q)$ $(q = u, d, s)$
  Simulate quark dressing (gluons and $q\bar{q}$ effects)
  Use **Vector Meson Dominance** parametrization
  GR and MT Peña, PRD 80, 013008 (2009); J. Phys. G **36**, 115011 (2009)
- Phenomenological $SU(6)$ meson cloud – octet baryon
  GR, K Tsushima and AW Thomas, JPG 40, 015102 (2013); GR and K Tsushima, PRD 84, 054014 (2011)



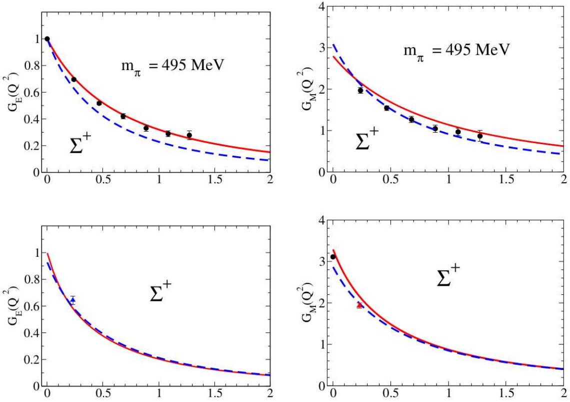




Octet baryon EM form factors: Physical & lattice QCD

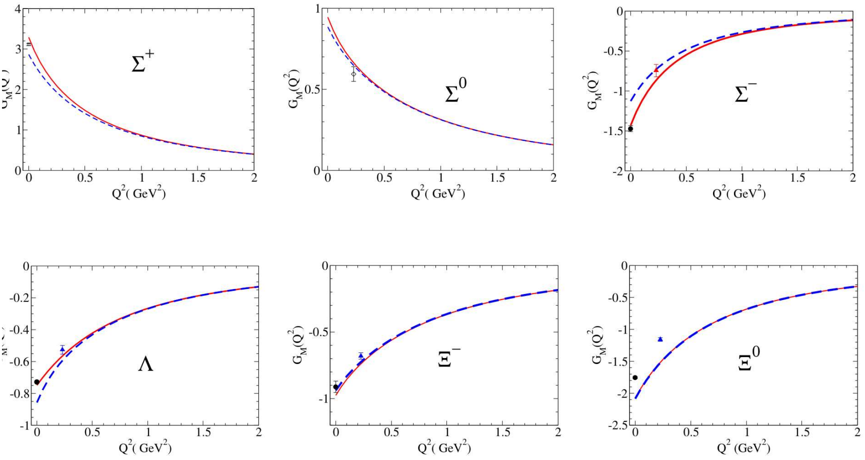
GR and K Tsushima, PRD 84, 054014 (2011)

- **Callibrate model** ——-
  Bare parameters
  using **lattice QCD**
  Fit radial wave functions
  $\psi_B(M_B \to \psi_B(M_B^{\rm latt})$
  Quark current fixed (VMD)
  $f_{i\ell}(Q^2, m_v, M_N) \to f_{i\ell}(Q^2, m_v^{\rm latt}, M_N^{\rm latt})$
- Extrapolate to physical limit
  $m_\pi \to m_\pi^{\rm phy}$ - - - - - -
- Include meson cloud
  $\Rightarrow$ Physical FF $\longrightarrow$
  $G_\ell = Z_B \left[G_\ell^{\rm B} + G_\ell^{\rm MC} \right]$
  Effective meson cloud



Model can be used to calculate **octet baryon FF** in **different ranges of** Q^2

Hyperons – Magnetic form factors – example



GR and K Tsushima, PRD 84, 054014 (2011)

Hyperon electromagnetic form factors in the timelike region

$$q^2 > 4M_B^2$$

large q^2 regime

Measurements of $|G|$ and $|G_E/G_M|$

PRD 101, 014014 (2020)

PLB 858, 139060 (2024)

Elastic form factors - Timelike vs Spacelike $Q^2 = -q^2$

Asymptotic relations between spacelike ($G_\ell^{\rm SL}$) and timelike ($G_\ell^{\rm TL}$) regions $\ell = E, M$

$$G_\ell(q^2) \stackrel{q^2 \to \infty}{=} G_\ell(-q^2)$$

Phragmèn—Lindelöf theorem, Pacetti, Ferroli, Tomasi-Gustafsson, Phys. Rep. 550, 1 (2015), App. D

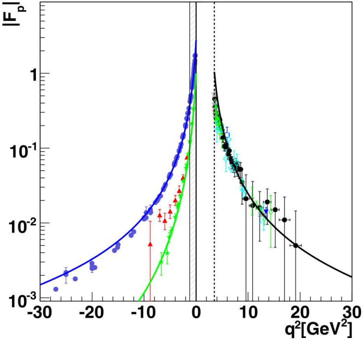
There is a gap between $]-\infty, 0]$ and $[4M^2, +\infty[$

Finite corrections (central value):

$$G_\ell^{\rm TL}(q^2) \simeq G_\ell^{\rm SL}(q^2 - 2M^2)$$

Kuraev, Dbeyssi, Tomasi-Gustafsson, PLB 712, 240 (2012)

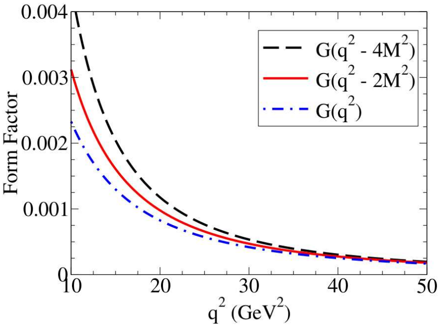
Proton form factors G_M, $|G_M|$

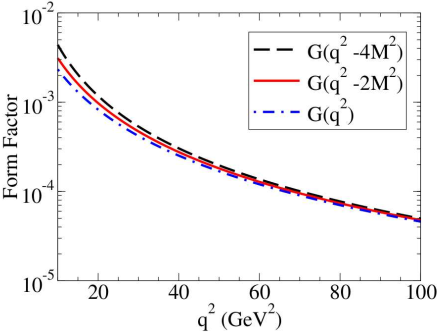


SL TL

Finite corrections to asymptotic result: $G^{\rm TL}(q^2) \simeq G(q^2 - 2M^2)$

Theoretical bands: Lower limit $q^2 \to q^2$ Upper limit: $q^2 \to q^2 - 4M^2$





$$G(Q^2) = \left(\frac{\Lambda_D^2}{\Lambda_D^2 + Q^2} \right)^2, \qquad \Lambda_D^2 = 0.71\text{GeV}^2$$

Theoretical uncertainties became **very small at large** q^2

Timelike form factors – Effective FF $|G(q^2)|$

$e^+e^- \to \gamma^* \to B\bar{B}$ – **Integrated** cross section

$G_E(q^2)$ and $G_M(q^2)$ **not measured** directly

Cross section: $\tau = \frac{q^2}{4M^2}$, $\beta = \sqrt{1 - \frac{1}{\tau}}$, $C \simeq 1$

$$\boldsymbol{\sigma}_{\mathbf{Born}} = \frac{4\pi\alpha^2\beta C}{3q^2}\left(1 + \frac{1}{2\tau}\right)|G(q^2)|^2$$

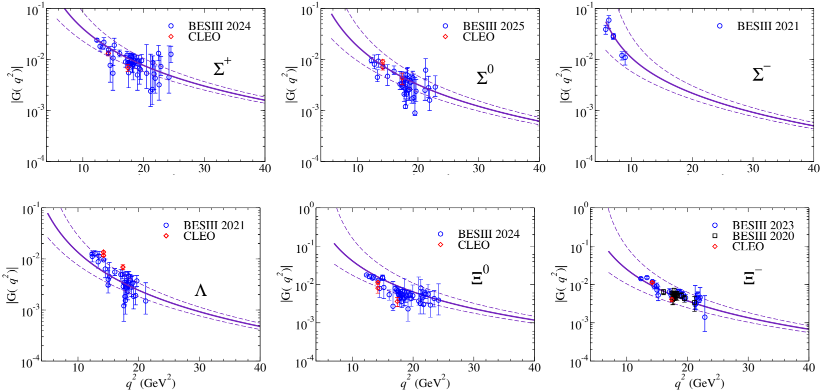
$$|G(q^2)|^2 = \frac{2\tau|G_M(q^2)|^2 + |G_E(q^2)|^2}{2\tau + 1}$$

Calculations: GR, MT Peña and K Tsushima PRD 101, 014014 **(2020)**

Ignore imaginary components and relative phases (**very large** q^2)

Data: CLEO ($q^2 = 14$, 17 GeV^2); New: BES III 2020, 2021, ..., 2025, 2026

Hyperon elastic form factors **at large** q^2 $(e^+e^- \to B\bar{B})$



New BES III data: Λ (2021); Ξ^- (2020, 2023); Σ^+ (2024); Ξ^0 (2024); Σ^0 **(2025)**

Σ^+, Σ^0, Λ, Ξ^-, Ξ^0: PRL 124, 032002 (2020); PLB 814, 136110 (2021); JHEP 11, 228 (2023);

PRD 109, 034029 (2024); PRD 111, L051502 (2025); CLEO, PRD 96, 092004 (2017);

GR, MT Peña, K Tsushima and MK Cheoun, PLB 858, 139060 (2024) — **Good agreement** $q^2 > 15$ **GeV**^{2}

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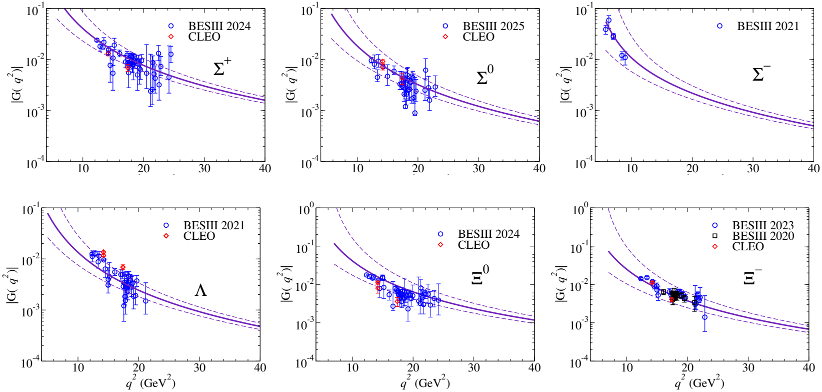

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PRD 109, 034029 (2024); PRD 111, L051502 (2025); CLEO, PRD 96, 092004 (2017); Σ^- **preliminary data (2026)**

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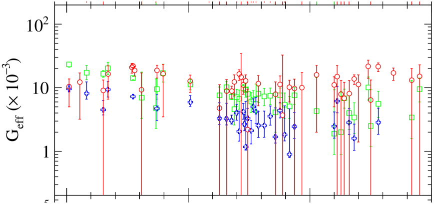
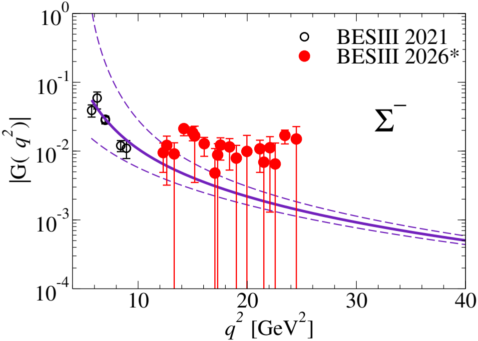
Hyperon elastic form factors **at large** q^2: Σ^-

BESIII, arXiv 2602.23835 [hep-ex]

preliminary data





BESIII data & **Model:** $|G(\Sigma^+)| > |G(\Sigma^0)|$

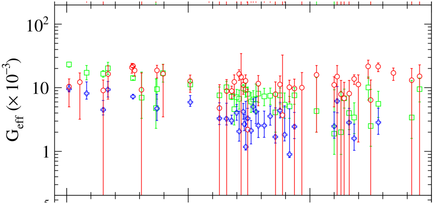
BESIII data: $|G(\Sigma^-)| > |G(\Sigma^+)|$!!

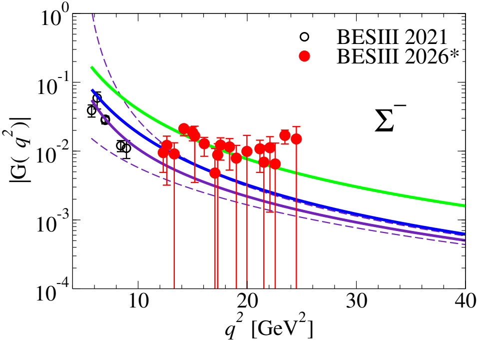
Model prediction: $|G(\Sigma^0)| > |G(\Sigma^-)|$

Hyperon elastic form factors **at large** q^2: Σ^-

BESIII, arXiv 2602.23835 [hep-ex]

preliminary data





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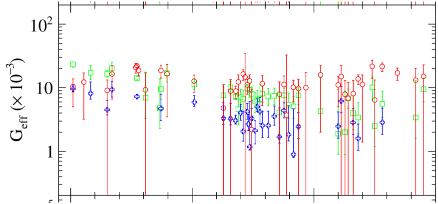
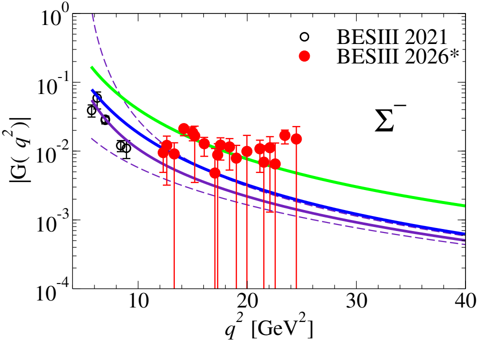
Hyperon elastic form factors **at large** q^2: Σ^-

BESIII, arXiv 2602.23835 [hep-ex]

preliminary data





BESIII data & **Model:** $|G(\Sigma^+)| > |G(\Sigma^0)|$

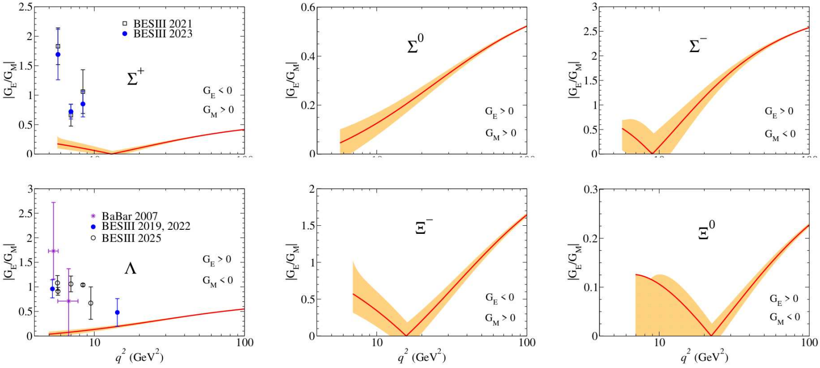
BESIII data: $|G(\Sigma^-)| > |G(\Sigma^+)|$!!

Model prediction: $|G(\Sigma^0)| > |G(\Sigma^-)|$

Lower limit compatible with **Model**

More precise data is needed for definitive conclusions

Hyperon ratios $|G_E/G_M|$



Model calculations for $|G_E|/|G_M|$ (real functions): much smaller than data

Σ^+, Λ: Data from BESIII 2021, 2022, 2023, 2025 & BaBar

PLB 814, 136110 (2021) PRD 105, L011101 (2022); PRL 132, 081904 (2024); PRL 135, 191902 (2025)

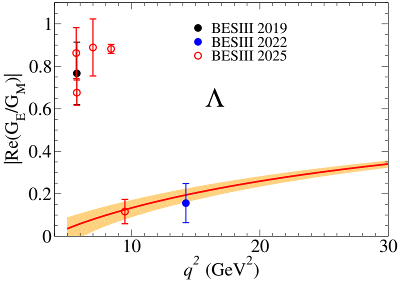
Model not comparable with data **OR Data not at the range of the calculations (large q^2)**

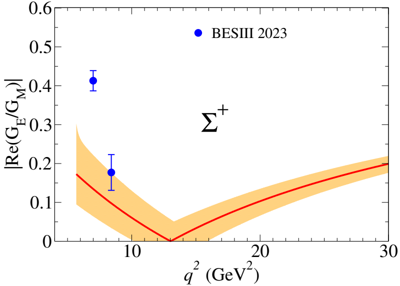
Hyperon ratios $|G_E/G_M|$ — Model vs Data BES III

Model calculations valid for the limit $\mathrm{Im}(G_E) = 0$, $\mathrm{Im}(G_M) = 0$

Data (real and imaginary parts): $\frac{G_E}{G_M} = \frac{|G_E|}{|G_M|} e^{i\Delta\Phi}$

PRD 105, L011101 (2022), PRL 135, 191902 (2025) PRL 132, 081904 (2024)





Compare model with **real part:** $\left|\mathrm{Re}\left(\frac{G_E}{G_M}\right)\right| = \frac{|G_E|}{|G_M|} |\cos(\Delta\Phi)|$

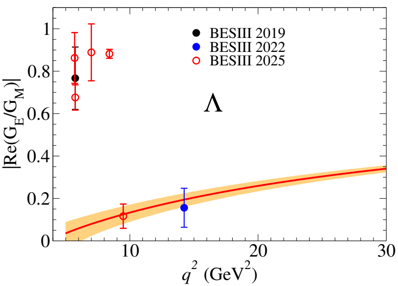
Model predictions for $\left|\mathrm{Re}\left(\frac{G_E}{G_M}\right)\right|$ – **Uncertainties $\Delta\Phi$ not included**

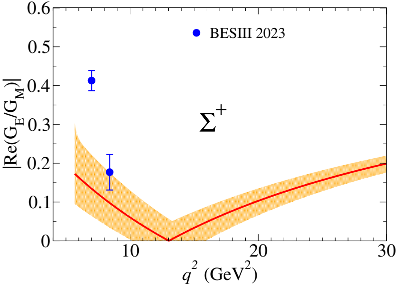
Hyperon ratios $|G_E/G_M|$ — Model vs Data BES III

Model calculations valid for the limit $\mathrm{Im}(G_E) = 0$, $\mathrm{Im}(G_M) = 0$

Data (real and imaginary parts): $\dfrac{G_E}{G_M} = \dfrac{|G_E|}{|G_M|} e^{i\Delta\Phi}$

PRD 105, L011101 (2022), PRL 135, 191902 (2025) PRL 132, 081904 (2024)





Compare model with **real part:** $\left|\mathrm{Re}\left(\dfrac{G_E}{G_M}\right)\right| = \dfrac{|G_E|}{|G_M|} |\cos(\Delta\Phi)|$

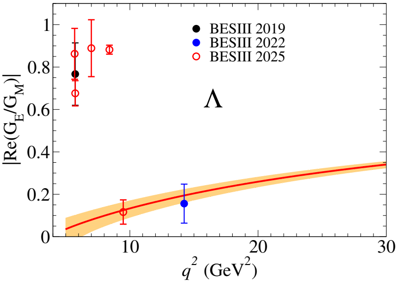
Model predictions for $\left|\mathrm{Re}\left(\dfrac{G_E}{G_M}\right)\right|$ – large q^2 data needed to test model

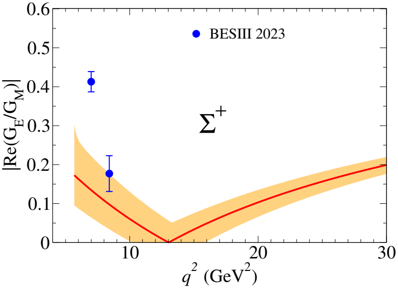
Hyperon ratios $|G_E/G_M|$ — Model vs Data BES III

Model calculations valid for the limit $\mathrm{Im}(G_E) = 0$, $\mathrm{Im}(G_M) = 0$

Data (real and imaginary parts): $\dfrac{G_E}{G_M} = \dfrac{|G_E|}{|G_M|} e^{i\Delta\Phi}$

PRD 105, L011101 (2022), PRL 135, 191902 (2025) PRL 132, 081904 (2024)





Compare model with **real part:** $\left|\mathrm{Re}\left(\dfrac{G_E}{G_M}\right)\right| = \dfrac{|G_E|}{|G_M|} |\cos(\Delta\Phi)|$

q^2 too low for conclusions; Test calculations w/ $q^2 \gtrsim 20$ GeV^2

Hyperon ratios $|G_E/G_M|$ – Model vs Data – Remarks

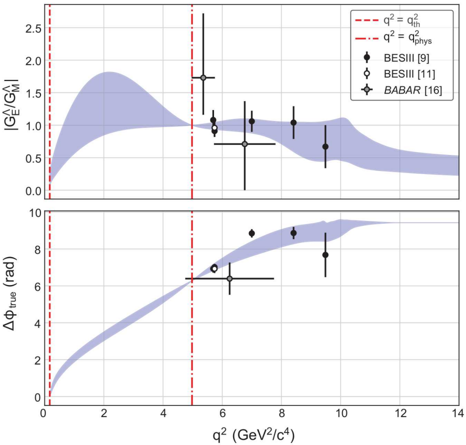
PRL 135, 191902 (2025)

Recent result: Λ – phase

- Λ form factors BES III
- Model: A. Mangoni, et al, PRD 104, 116016 (2021)
  $q^2 > 10$ GeV^2
  $\Delta\Phi = 3\pi \;(e^{i\Delta\Phi} = -1)$

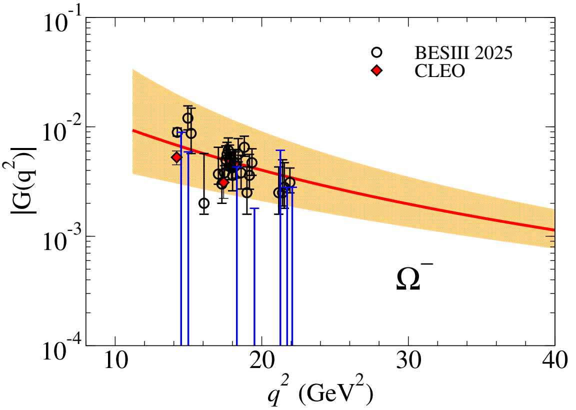
Model:

- Λ Form Factors:
  $q^2 \gtrsim 10$ GeV^2
  $\left|\mathrm{Re}\left(\frac{G_E}{G_M}\right)\right| \approx \frac{|G_E|}{|G_M|}$
- **Global model** for the octet baryon **hyperons** Λ, Σ, Ξ



Ω^- form factors: Model and data

Predictions of Ω^- effective FF: **GR, PRD 103, 074018 (2021)**
Global fit to Ω^- data (SL data: weight 96.3%)



New BES III data: **JHEP 2026, 212 (2026)** upper limit of $|G| = 0$ – blue lines

Outlook and conclusions

- Covariant Quark Model developed for spacelike region $(q^2 = -Q^2 < 0)$
  Describes Lattice QCD (bare) & Physical data (MC dressing)
- Model extended to **elastic timelike region** $q^2 > 4M_B^2$
  Opportunity to study dynamical structure of hyperons $(q^2 \neq 0)$
  Large q^2 (asymptotic relations)
  - **Unified model for Λ, Σ, Ξ**
  - Predictions for effective FF $|G(q^2)|$: Data $q^2 \gtrsim 15$ GeV^2
    Compatible with **new q^2 data** within **theoretical bands** (Σ^- ?)
  - Predictions for $\left|\mathrm{Re}(\frac{G_E}{G_M})\right|$:
    Expected slower convergence of model w/ data [neglegible $\mathrm{Im}(G_\ell)$]
    Precise data for $\Delta\Phi$ needed; Promising results for Λ
    Model calculations may be tested: $q^2 \gtrsim 20$ GeV^2 data $\left(\left|\frac{G_E}{G_M}\right|, \Delta\Phi\right)$
- **Future:** nucleon $|G_E/G_M|$, Heavy baryons, **Inelastic reactions**
  We have preliminary calculations for $e^+e^- \to \Lambda\overline{\Sigma^0}$ FF

Thank you

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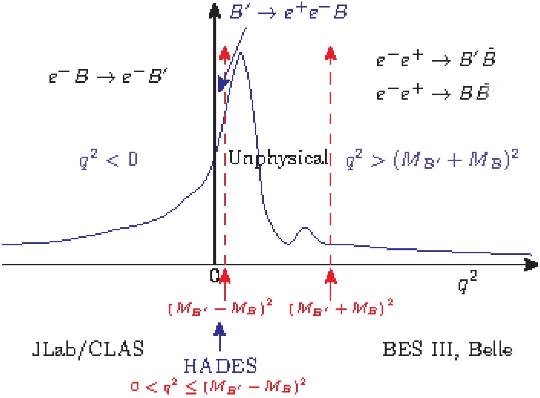
New calculations – Timelike/large-q^2 region



Elastic: nucleon $|G_E/G_M|$, phase; Heavy baryons Λ_c^+ ...

Inelastic: $\Lambda\overline{\Sigma^0}$, $N\overline{N^*}$, $\Xi\bar{\Xi}(1530)$ (octet-decuplet), $\Lambda_c^+\bar{\Lambda}_c(2625)^-$... transition FF

Outlook and conclusions

- Covariant Quark Model developed for spacelike region $(q^2 = -Q^2 < 0)$
  Describes Lattice QCD (bare) & Physical data (MC dressing)
- Model extended to **elastic timelike region** $q^2 > 4M_B^2$
  Opportunity to study dynamical structure of hyperons $(q^2 \neq 0)$
  Large q^2 (asymptotic relations)
  - **Unified model for Λ, Σ, Ξ**
  - Predictions for effective FF $|G(q^2)|$: Data $q^2 \gtrsim 15$ GeV^2
    Compatible with **new q^2 data** within **theoretical bands** $(\Sigma^-\ ?)$
  - Predictions for $\left|\mathrm{Re}(\frac{G_E}{G_M})\right|$:
    Expected slower convergence of model w/ data [neglegible $\mathrm{Im}(G_\ell)$]
    Precise data for $\Delta\Phi$ needed; Promising results for Λ
    Model calculations may be tested: $q^2 \gtrsim 20$ GeV^2 data $\left(\left|\frac{G_E}{G_M}\right|, \Delta\Phi\right)$
- **Future:** nucleon $|G_E/G_M|$, Heavy baryons, **Inelastic reactions**
  We have preliminary calculations for $e^+e^- \to \Lambda\overline{\Sigma^0}$ FF

Thank you 🙂

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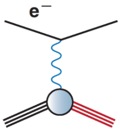
Selected bibliography

Electromagnetic transition form factors of baryon resonances,
G. Ramalho and M. T. Peña, **Prog. Part. Nucl. Phys. 136, 104097 (2024).**

- Model for the octet baryon/decuplet baryon – spacelike region
  - **Octet baryon electromagnetic form factors in nuclear medium,** G. Ramalho, K. Tsushima and A. W. Thomas, **J. Phys. G 40, 015102 (2013).**
  - **Octet baryon electromagnetic form factors in a relativistic quark model,** G. Ramalho and K. Tsushima, **Phys. Rev. D 84, 054014 (2011).**
  - **Relativistic quark model for the Ω^- electromagnetic form factors,** G. Ramalho, K. Tsushima and F. Gross, **Phys. Rev. D 80, 033004 (2009).**
- Extension of model to the timelike region
  - **Hyperon electromagnetic timelike elastic form factors at large q^2,** G. Ramalho, M. T. Peña and K. Tsushima, **Phys. Rev. D 101, 014014 (2020).**
  - **Electromagnetic form factors of the Ω^- baryon in the spacelike and timelike regions,** G. Ramalho, **Phys. Rev. D 103, 074018 (2021).**
  - **Electromagnetic $|G_E/G_M|$ ratios of hyperons at large q^2,** G. Ramalho, M. T. Peña, K. Tsushima and M.-K. Cheoun, **Phys. Lett. B 858 139060 (2024).**

Additional Information

Spacelike and timelike reactions – elastic case



TFF

JLab/CLAS:

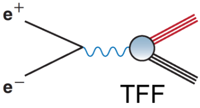
most world data

Spacelike reactions:

$e^- N \to e^- N$ $(e^- B \to e^- B)$

G_E, G_M real functions (2 numbers)

- Rosenbluth separation method
  $\frac{d\sigma}{d\Omega} \propto \left(\tau G_M^2 + \epsilon G_E^2\right)$, $(\tau = \frac{Q^2}{4M^2}, \; \epsilon^{-1} \propto \tan^2 \frac{\theta}{2} + ...)$
- Transfer polarization method: $\frac{G_E}{G_M}$



BES III, BELLE II

Timelike reactions: $e^- e^+ \to \gamma^* \to B\bar{B}$

G_E, G_M complex functions ($|G_E|$, $|G_M|$, $\Delta\Phi =$ rel. phase)

- Differential cross-section (one-γ-exchange)
  $\frac{d\sigma}{d\Omega} = \frac{\alpha^2 \beta C}{4q^2}\left[|G_M|^2(1+\cos^2\theta) + \frac{1}{\tau}|G_E|^2 \sin^2\theta\right]$
- Integrated cross-section $(\tau = \frac{q^2}{4M^2})$
  $\sigma(q^2) = \frac{4\pi\alpha^2\beta C}{3q^2}\left[|G_M|^2 + \frac{1}{2\tau}|G_E|^2\right]$
  [...] define effective form factor

Formalism

CSQM: Octet wave function (1)

S-state approximation (quark-diquark) P: Baryon; k: diquark

F Gross, GR and K Tsushima, PLB 690, 183 (2010):

$$\Psi_B(P,k) = \frac{1}{\sqrt{2}}\left[|M_S\rangle\Phi_S^0 + |M_A\rangle\Phi_S^1\right]\psi_B(P,k)$$

$|M_S\rangle, |M_A\rangle$: flavor states; $\Phi_S^{0,1}$: spin states

B	$\lvert M_S\rangle$	$\lvert M_A\rangle$
p	$\frac{1}{\sqrt{6}}\left[(ud+du)u-2uud\right]$	$\frac{1}{\sqrt{2}}(ud-du)u$
n	$-\frac{1}{\sqrt{6}}\left[(ud+du)d-2ddu\right]$	$\frac{1}{\sqrt{2}}(ud-du)d$
Λ^0	$\frac{1}{2}\left[(dsu-usd)+s(du-ud)\right]$	$\frac{1}{\sqrt{12}}\left[s(du-ud)-(dsu-usd)-2(du-ud)s\right]$
Σ^+	$\frac{1}{\sqrt{6}}\left[(us+su)u-2uus\right]$	$\frac{1}{\sqrt{2}}(us-su)u$
Σ^0	$\frac{1}{\sqrt{12}}\left[s(du+ud)+(dsu+usd)-2(ud+du)s\right]$	$\frac{1}{2}\left[(dsu+usd)-s(ud+du)\right]$
Σ^-	$\frac{1}{\sqrt{6}}\left[(sd+ds)d-2dds\right]$	$\frac{1}{\sqrt{2}}(ds-sd)d$
Ξ^0	$-\frac{1}{\sqrt{6}}\left[(ud+du)s-2ssu\right]$	$\frac{1}{\sqrt{2}}(us-su)s$
Ξ^-	$-\frac{1}{\sqrt{6}}\left[(ds+sd)s-2ssd\right]$	$\frac{1}{\sqrt{2}}(ds-sd)s$

CSQM: Octet wave function (2) SU(3) breaking

Radial wave functions: $\psi_B[(P-k)^2]$
Defined in terms of

$$\chi_B = \frac{(M_B - m_D)^2 - (P-k)^2}{M_B m_D}$$

$$\psi_N(P,k) = \frac{N_N}{m_D(\beta_1 + \chi_N)(\beta_2 + \chi_N)}$$

$$\psi_\Lambda(P,k) = \frac{N_\Lambda}{m_D(\beta_1 + \chi_\Lambda)(\beta_3 + \chi_\Lambda)}$$

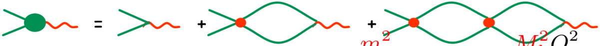
$$\psi_\Sigma(P,k) = \frac{N_\Sigma}{m_D(\beta_1 + \chi_\Sigma)(\beta_3 + \chi_\Sigma)}$$

$$\psi_\Xi(P,k) = \frac{N_\Xi}{m_D(\beta_1 + \chi_\Xi)(\beta_4 + \chi_\Xi)}$$

β_i: momentum range parameters (m_D units); $\beta_4 > \beta_3 > \beta_2 > \beta_1$
long range: β_1 (all systems)
short range: β_2 (lll systems); β_3 (sll systems); β_4 (ssl systems)

CSQM: Photon-Quark coupling [Extra]

- $j_q^\mu = j_1 \gamma^\mu + j_2 \frac{i\sigma^{\mu\nu} q_\nu}{2M_N}$, Quark form factors: $j_i = \frac{1}{2} f_{i+} \lambda_0 + \frac{1}{6} f_{i-} \lambda_3 + \frac{1}{2} f_{i0} \lambda_s$
  [parametrize gluon and $q\bar{q}$ dressing of quarks] λ_l: Gell-Mann matrices
  Vector meson dominance parameterization: PRD 80, 033004 (2009)



$$f_{1\pm} = \lambda_q + (1-\lambda_q) \frac{m_v^2}{m_v^2 + Q^2} + c_\pm \frac{M_h^2 Q^2}{(M_h^2 + Q^2)^2}$$

$$f_{10} = \lambda_q + (1-\lambda_q) \frac{m_\phi^2}{m_\phi^2 + Q^2} + c_0 \frac{M_h^2 Q^2}{(M_h^2 + Q^2)^2}$$

$$f_{2\pm} = \kappa_\pm \left\{ d_\pm \frac{m_v^2}{m_v^2 + Q^2} + (1-d_\pm) \frac{M_h^2}{M_h^2 + Q^2} \right\}$$

$$f_{20} = \kappa_0 \left\{ d_0 \frac{m_\phi^2}{m_\phi^2 + Q^2} + (1-d_0) \frac{M_h^2}{M_h^2 + Q^2} \right\}$$

Light mesons ($m_v = m_\rho$), m_ϕ and **effective** heavy meson: $M_h = 2M_N$
Fix coefficients (c_0, $c_\pm$, d_0, $d_+ = d_-$) and a. m. m. $\kappa_\pm$, κ_0, – universal parameters
Use: Nucleon EM form factors; lattice QCD data (decuplet baryon)